Case Report

Fixation Technique and Outcomes for Achilles Tendon Sleeve Avulsion Injury From the Calcaneus: A Case Series and Review of the Literatures

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Objective: Surgical treatment of Achilles tendon sleeve avulsion from its insertion is challenging. The purpose of this study is to report a surgical technique for Achilles tendon sleeve avulsion injuries including outcomes and complication in four patients.

Materials and Methods: A prospective case series of Achilles tendon sleeve avulsion injuries which underwent open gastrocnemius lengthening, calcaneal exostectomy, debridement of the Achilles tendon, and reattachment of the Achilles tendon to the calcaneus using double-row SutureBridge™ technique was conducted. Patient self-reporting questionnaires and outcome measures including general health (Short Form-36 [SF-36]), region-specific outcomes (Foot and Ankle Ability Measure [FAAM]), and pain measure (Visual Analogue Scale [VAS]) were recorded at pre- and final post-operative visits.

Results: Four male patients, mean age of 52 years, were included in this study. An average follow-up time was 15 months (range 12 to 18 months). There was significant improvement of SF-36 (25.4, 28.5, 24.1, and 28.7 which were improved to 50.5, 55.2, 51.7, and 52.8 for PCS and 42.4, 48.8, 45.2, and 46.2 which were improved to 55.9, 56.7, 54.3, and 59.8 for MCS); FAAM (60, 67, 65, and 68 which decreased to 21, 30, 30, and 33 for ADL and 0, 0, 0, and 0 which improved to 72, 70, 69, and 66 for sports); and VAS score (5, 7, 6, and 8 which decreased to 0, 0, 0, and 0) for the first, second, third, and fourth patients, respectively. All patients returned to daily activities and work at 6 weeks and returned to sports activities approximately 6 months post-operatively. There were no complications in this study.

Conclusion: The SutureBridge™ technique appears to be an effective technique which has demonstrated promising results with minimal complications for treatment of Achilles tendon sleeve avulsion injury.

Keywords: Achilles Tendon Sleeve Avulsion, Achilles Tendon Rupture, Achilles Tendinopathy, SutureBridge technique

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Acute rupture of Achilles tendon is one of the most common types of tendon rupture in athletes[1]. Midsubstance tear is the most common site of injury located approximately 2 to 6 cm above its insertion which is resulted from relative hypovascularity[2]. Unlike midsubstance ruptures, a sleeve avulsion Achilles tendon injury is a rare condition which is defined as a detachment from its insertion. It can present either with or without small bony fragments[3-5]. Occasionally, this injury can overlap with a calcaneal tuberosity avulsion fracture (about 2.6 percent of calcaneal fractures)[6]. The avulsion type usually occurs in older individuals, individuals with osteoporosis, females, and individuals with diabetes, gastrocnemius contracture, or complications after corticosteroid injection[4,5]. Beavis et al described three types of calcaneal tuberosity avulsion fractures; both type I and type III fractures are considered to be sleeve avuision injury because they involve an Achilles tendon injury with a small shell or fragment of cortical bone avulsed from the calcaneal tuberosity[7].

Surgical repair of sleeve avulsion injuries is more difficult than end-to-end midsubstance injuries. Providing a secure fixation is a challenging problem for orthopedic surgeons because of potential problems

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with inadequate bony fixation, high pull-out tension from the triceps surae, and poor bone quality. Several techniques have been reported to be successful treatment for sleeve avulsion injury including tension band wiring[8], suture fixation through bone tunnels[9-11], TightRope®[12], and various of Suture Bridge™ construct techniques[13,14].

The present study reported 4 cases of sleeve avulsion injury of Achilles tendon that underwent reattachment of the Achilles tendon using the double-row SutureBridge™ technique, two 5.5 mm X 20 mm Bio-SwiveLock® Suture Anchors and two 4.75 mm x 20 mm SwiveLock® system suture anchors. In addition, we presented a comprehensive review of surgical techniques described in the literatures for treatment of patients with an Achilles tendon sleeve avulsion injury.

Case Report

The first case was a 60-year-old Thai male who presented with sudden left heel pain 1 day prior to the hospital. He had a coronary artery disease. His height was 165 cm and his body weight was 78 kg (BMI 28.7 kg/m^2). He had experienced pain in his heel for three years but the pain in his left heel became severe after he jumped down from a ladder. He could not walk or stand after the injury. Physical examination showed that his ankle was significantly swollen, tender, and extensive ecchymosis on the posterior ankle and distal calf area. The Thompson test was positive, he had loss of plantar flexion strength, slightly ankle dorsiflexion in the resting position compared to the normal ankle. There was a palpable gap and palpable a bony fragment. The plain radiograph showed a bony fragment of calcaneal tuberosity, 0.5x0.6 cm with proximal retraction approximately 3.0 cm, above its insertion to the calcaneus (Figure 1A). The sagittal T1-weighted, T2-weighted, and STIR MR images showed an approximately 1.0 x 0.8 cm bony fragment at the distal part of the Achilles tendon (Figure 2).

The second case was a 31 year-old Thai male who presented with sudden pain on the right heel which started during a basketball game. He was healthy with no underlying disease. His height was 190 cm and his weight was 100 kg (BMI 27.7 kg/m^2). When he landed on his right foot after a rebound, he heard a popping sound in his right heel which felt like he had been kicked on the back of his ankle. He experienced severe pain on his right heel and could not walk by himself after the injury. Physical examination showed his ankle was significantly swollen, tender, and extensive ecchymosis on the posterior ankle and distal calf areas. The Thompson test was positive, he had loss of plantar flexion strength, slightly ankle dorsiflexion in the resting position compared to normal ankle, and a palpable gap with a bony fragment. The plain radiograph showed a 1.0x0.8 cm bony fragment of calcaneal tuberosity with proximal retraction of approximately 2.5 cm above the insertion into the calcaneus (Figure 1B).

The third case was a 56 year-old Thai male, who presented with sudden pain in his left heel one hour prior to hospitalization. His height was 176 cm and his body weight was 105 kg. He had been experiencing severe pain in his left heel for the previous 3 months and had received a cortisone injection at the insertion of the Achilles tendon from an orthopaedic surgeon 2 months earlier. He reported he was pain-free after the injection and walked normally for 6 weeks. Then he had sudden pain on the back of his ankle when he stood up from a chair. Physical examination showed his ankle was significantly swollen, tender, and extensive ecchymosis on the posterior ankle and distal calf area. The Thompson test was positive, he had loss of plantar flexion strength, slight ankle dorsiflexion in the resting position compared to the normal ankle, and

Figure 1. Lateral view of the ankle showing a small avulsion fragment in the first and second patients (A and B) and no bony avulsion in the third patient (C).

Figure 2. Sagittal T1-weighted (A), T2-weighted (B), and STIR MR (C) images showing a bony fragment approximately 1.0x0.8 cm at the distal part of the Achilles tendon which had been avulsed from the calcaneal tuberosity.

a palpable gap with the bony fragment. The plain radiograph showed a normal contour of the posterior calcaneus and no bony fragments posterior to the ankle joint (Figure 1C). The sagittal T1-weighted and T2-weighted MR image showed sleeve avulsion of the Achilles tendon from the distal part of the calcaneus with a very short stump on the posterosuperior part of the calcaneus (Figure 3).

The fouth case was a 60 year-old Thai male, who presented with sudden pain in his left heel which began while he was playing tennis. He was healthy with no underlying disease. His height was 180 cm and his body weight was 82 kg (BMI 25.3 kg/m^2). While jumping on his left foot during a tennis game, he felt a sharp pain at the back of his left ankle. He experienced severe pain on his left heel and could not stand or walk by himself after the injury. Physical examination showed his lower leg was significantly swollen, tender, and had extensive ecchymosis on the posterior ankle. The Thompson test was positive, he had loss of plantar flexion strength, slightly ankle dorsiflexion in the resting position compared to the normal ankle, and a palpable gap. The plain radiograph showed no bony fragment.

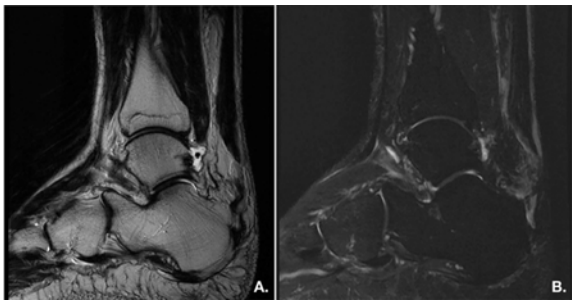

Figure 3. Sagittal T1-weighted (A) and T2-weighted (B) MR images showing sleeve avulsion of the Achilles tendon from the distal part of the calcaneus.

Operative technique

The patients were placed in a prone position and given either a spinal block or general anesthesia. The affected leg was prepped and draped with a thigh tourniquet. An 8-cm posterior midline incision (Figure 4) was made and deepened through the subcutaneous tissue. The paratenon was identified and carefully dissected. Thereafter, the distal stump was identified, split, and debrided to create a stable distal rim (Figure 4A). In two of the 4 patients, a small fragment of calcaneal tuberosity was found and removed from the distal part of Achilles tendon. Then posterosuperior part of the calcaneus (Haglund's deformity) was identified and was cut obliquely from inferior-distal (3 to 5 mm distal to the Achilles tendon insertion) to superior-proximal direction (1.0 to 1.5 cm anterior to the posterosuperior border of the calcaneus) to prevent impingement on Achilles tendon and to prepare a good vascular bed for reattachment of the Achilles tendon. One patient had poor tissue quality at the distal end of the Achilles tendon due to a previous corticosteroid injection. After adequate debridement, there was a relative shortening of the Achilles tendon compared to the previous condition. One patient had a rupture approximately 1.0 cm above the insertion to the calcaneus; after debridement of the remaining distal stump and Haglund's deformity, there was a shortening

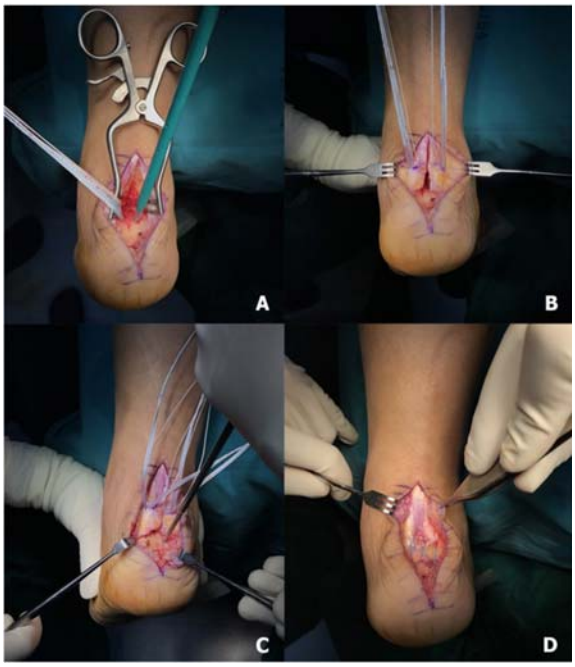

Figure 4. A posterior midline skin incision was used with two suture anchors inserted at the proximal row (A and B) and two suture anchors inserted at the distal row (C). Complete reattachment using the double-row SutureBridge technique is shown in (D).

of the Achilles tendon when it was brought down to the calcaneus. Both patients then underwent lengthening of the gastrocnemius and soleus fascia (Valpius procedure) to allow ankle dorsiflexion of 5 degrees with the knee fully extended and 10 degrees with the knee flexed 90 degrees. Thereafter, reattachment of the Achilles tendon process was performed using

the SutureBridge technique. Two double-loaded 5.5-mm SwiveLock® suture anchors with fibertape were inserted at the proximal row (Figure 4A and 4B) to cover the proximal footprint and two 4.75 mm Bio-SwiveLock® suture anchors were inserted at the distal row (Figure 4C). Then the fibertape was tied and brought to the distal part of the tendon down to the new footprint using the SutureBridge technique (Figure 4D). Fixation was checked by performing a squeeze test on the calf area and tension was tested by performing dorsiflexion of the ankle joint to approximately 5 degrees of dorsiflexion with the knee fully flexed. Skin and soft tissue was copiously irrigated and the paratenon was closed with 3-0 absorbable suture (Vicryl) and the skin was closed with 4-0 non-absorbable suture (nylon). A soft dressing was applied and a posterior splint was applied in the 30-degree plantarflexed position.

Post-operative rehabilitation

The patients were instructed to be non-weight bearing with a below the knee posterior splint for 2 weeks. A post-operative radiograph was made to evaluate the calcaneal tuberosity (Figure 5A and 5B). At 2 weeks, the wounds were checked and all stitches were removed (Figure 6A and 6B). At 2 to 4 weeks the patients were placed in a CAM walking boot with 3-cm heel wedge in a non-weight bearing fashion. At 4 to 6 weeks, the patients were allowed to perform partial weight bearing in the CAM walking boot with heel wedge and to continue range of motion exercise of the ankle joint. After 6 weeks, the patients were allowed to progress to full weight bearing in the CAM walking boot with a 3-cm heel wedge. Then the patients were instructed to gradually wean themselves from the heel wedge by removing a 1-cm heel wedge each week. They could perform daily activities and return to work after 6 to 8 weeks and return to sports after 4 to 6 months when they were pain free and could perform a single leg heel raise. There were no complications during the intra-operative or post-operative period of this study. The clinical outcomes at the final post-operative visit are shown in Figure. 7A to 7D.

Functional outcome measurement

The 4 male patients enrolled in this study were matched for inclusion criteria. Average follow-up time was 15 months (range 12 to 18 months). Patient self-reporting questionnaires included general health measures, i.e., Short Form-36 [SF-36], Physical Component Subscale [PCS], and Mental Component Subscale [MCS]; region-specific outcomes measures, i.e., Foot and Ankle Ability Measure [FAAM], activities of daily living subscale, and sports subscale; and a pain score measure, the Visual Analogue Scale [VAS]. All scores were recorded at both the pre-operative and the final post-operative visits. SF-36 values improved from 25.4, 28.5, 24.1, and 28.7 to 50.5, 55.2, 51.7, and 52.8; PCS improved from 42.4, 48.8, 45.2, to 46.2 to 55.9, 56.7, 54.3, and 59.8 for MCS at the pre-operative and final post-operative visits for the first, second, third,

Figure 5. Lateral view of the ankle joint demonstrating the shape of the calcaneal tuberosity after calcaneal exostectomy (debridement of Haglund's deformity) as well as the metal suture anchors for proximal-row and biocomposite distal-row suture anchors (A) and biocomposite sutures for both proximal-row and distal-row suture anchors (B).

Figure 6. The posterior midline skin incision for reattachment of the Achilles tendon and posteromedial skin incision for open gastrocnemius recession and incision at 1 week (A) and at 2 weeks (B) post-operatively.

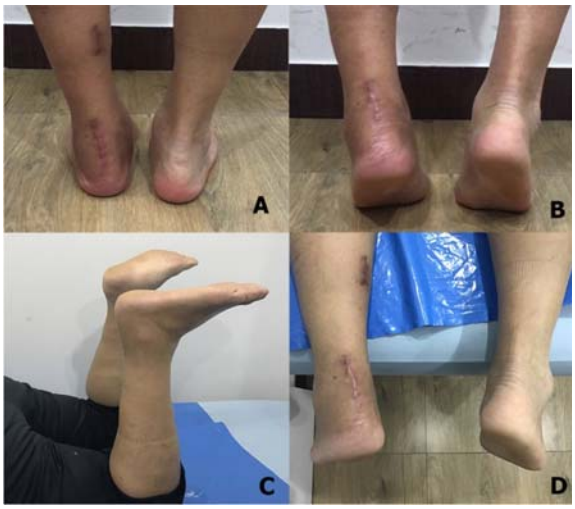

Figure 7. Clinical outcomes at the final post-operative visit. Wound incision at the final post-operative visit (A), heel raise test (B), resting position of ankle with both knees bent 90 degrees (C), and both knees fully extended (D).

and fourth patients, respectively. The pre-operative FAAM declined from 60, 67, 65, and 68 to 21, 30, 30, and 33 at the final post-operative visit for daily living activities. The pre-operative sports subscale was 0, 0, 0, and 0 and improved to 72, 70, 69, and 66 at the final post-operative visit. The pre-operative VAS scores of 5, 7, 6, and 8 and decreased to 0, 0, 0, and 0 at the final post-operative visit. All patients returned to daily activities and were able to return to work 6 weeks post-operatively. Patients were instructed to do double-heel raise exercises after 3 months and to perform single-heel raise exercises after 4 months (Figure. 7A and 7B). When they were able to do single-heel raise exercises and had no pain and good strength in the Achilles tendon, they were allowed to start gentle sport activities such as swimming and bicycling, gradually resuming participation in contact sports activities in two or three months. The average time to return to gentle sports with minimal discomfort in the posterior heel was 4 months, and they were able to return to their pre-injury level of sports with symptom-free 6 months post-operatively.

Literature review

Methods

A systematic review of PUBMED from 1998 to 2017 for the following pairs of terms, "Achilles tendon" and "avulsion", "calcaneal tuberosity" and "avulsion", "Achilles tendon" and "sleeve avulsion", identified eight full English language articles all of which were analyzed in this study. Emphasis was placed on sleeve avulsion and Achilles tendon rupture with small calcaneal tuberosity avulsion fracture (a small fragment that cannot be fixation fixation), demographic data (age and gender), mechanism of injury, size of bony fragment, operative techniques, outcomes, and complications.

Results

The eight articles included 32 patients (21 male and 10 female, with no gender information for 1 patient). The average age was 48.6 years (range 24 to 72). Inclusion criteria included sleeve avulsion and Achilles tendon rupture with small calcaneal tuberosity avulsion fracture. The most common cause of Achilles tendon rupture was trauma (19 patients, 59%) followed by sports injury (9 patients, 28%), while 4 patients (13%) had no information.

Nine patients (28%) had no bony attachment at the distal part of the Achilles tendon while 10 (31%) had a small fragment calcaneal tuberosity avulsion fracture with Achilles tendon rupture, and 13 (41%) had no information.

Most of the patients (21 patients, 66%) had a prodromal symptom of Achilles tendon pain before the rupture while 5 (16%) had no symptoms before the onset of rupture, and for 6 (19%) there was no information.

In 17 patients (53%), a posterior midline skin incision was used, while 15 (47%) had a posteromedial skin incision. Anchor sutures (2-4 anchors) were used in 25 patients (78%), the most common instrument for reattachment of the Achilles tendon to the calcaneus, while transcalcaneal suturing was used in 7 (22%). Gastrocnemius recession (4 patients, 13%) was a commonly performed simultaneously with the Achilles tendon reattachment.

Most patients reported significant improvement after surgery. However, as a variety of different instruments were used for outcome evaluation, e.g., AOFAS (17 patients, 53%), Japanese society for surgery of foot ankle/hindfoot scale (5 patients, 17%), patient reporting good to excellent results (7 patients, 22%), with 2 patients providing no outcome measurement, direct comparison was problematical.

A few complications were reported, the most common being delay wound healing (2 patients, 7%). One patient (3.2%) had a re-rupture of the Achilles

tendon proximal to the reattachment. Details of demographic data, surgical techniques, outcomes, and complications are shown in Table 1.

Discussion

Sleeve avulsion of the Achilles tendon and Achilles tendon rupture with small calcaneal tuberosity fragment are rare conditions, with only thirty-two cases reported in the English literature since 1998[3-12]. Based on literature review, this injury can occurred either from a traumatic event (59%) or a sport injury (28%) (Table 1). In the present case series, two patients had a history of trauma (one major and one minor trauma) and two patients had been injured during sports activities, similar to the literature. However, the patient who had minor trauma event by suddenly standing up from a sitting position had recently undergone a cortisone injection at the insertion of the Achilles tendon which is a predisposing factor that can decrease the strength of tendon and increase the chance of a tendon rupture. Additionally, corticosteroid injection is not recommended for insertional Achilles tendinopathy[15]. In addition, all four patients had a prodromal symptom before the Achilles tendon rupture, which is in line with previous studies in which the majority of the patients (66%) had experienced pain at the insertion of the Achilles tendon (tendinopathy) before the injury. Patients who have insertional Achilles tendinopathy are at risk for Achilles tendon sleeve avulsion and should be careful regarding participation in contact activities and sports activities.

Treatment of sleeve avulsion and Achilles tendon rupture with small calcaneal tuberosity avulsion fragment is surgically challenging[3-7,11]. Several techniques have been proposed in the literature, including transcalcaneal suture and various techniques for anchoring sutures[3-5,7,11]. However, a single-row construct of anchor sutures has been commonly used for reattachment of Achilles tendon rupture[3,16-18]. With the four patients in this study, we used a double-row construct of anchor sutures, so-called SutureBridge technique, which has been successfully used previously for treatment of insertional Achilles tendinopathy[13,14,19]. In addition, biomechanical studies have demonstrated that the double-row construct for reinsertion of a completely detached Achilles tendon using proximal and distal rows results in a significantly larger contact area and leads to significantly higher peak load failure[20,21]. The SutureBridge technique should be better than transcalcaneal suture in terms of pain from surgical scarring or to tying a knot at the bottom of the calcaneus with no need to drill long holes to into the calcaneus tuberosity that can weaken the calcaneus[4].

There can be minor complications following reattachment of sleeve avulsion or Achilles tendon rupture with small bony fragment. According previous studies, the most common complications after reattachment are delayed wound healing (7%) and rerupture above the level of reattachment (3.2%)[3,5,17]. However, our study found no complications following the double-row SutureBridge technique. Published reports indicated that the posterior midline skin incision is the most commonly used for reattachment of the Achilles tendon (53% of 31 patients)[3,11,18], while the posteromedial incision was use for 15 patients (47%)[5,16,17,22], with wound complications from the posteromedial and posterior midline incisions of 6.7% and 5.9%, respectively. The reduction in the rate of wound complications compared earlier reports may be directly related to the angiosome theory[23]. Posterior midline skin incision is recommended for Achilles tendon procedures because the two angiosomes supplying soft tissue to posterior heel consist of calcaneal branch from posterior tibial artery supplying the medial side of the heel and calcaneal branch from peroneal artery which supplies the lateral side of the heel[19,23].

In the four cases included in this study, the authors found that the prodromal symptom of posterior ankle pain were a warning sign in patients who had Achilles tendon sleeve avulsion injury. All four patients in this study required a calcaneal exostectomy and debridement of the Achilles tendon due to Haglund's deformity and thickening of Achilles tendon before reattachment to a new footprint. We found that the SutureBridge technique using a double-row anchor suture configuration was secure enough to allow the patients to perform range of motion and weightbearing as tolerated earlier, between 3 and 4 weeks post-operatively. All the patients returned to normal daily living activities and were released to return to work at 6 weeks post-operatively. The average time to return to sports was 4 months, with minimal discomfort in the posterior heel, and they were able to return to their previous level of sports at 6 months post-operatively.

Conclusion

A sleeve avulsion type of Achilles tendon rupture is a rare condition that occur in both young and older patients. Corticosteroid injection at the insertion of Achilles tendon can increase the risk of

Table 1. Literatures review demonstrate demographic data, outcomes, and complications in patients who had sleeve avulsion or small tuberosity avulsion fracture of calcaneus

Year, Authors	No.	Age	Sex	Cause	Underlying diseases	Mechanism of injury	Pre-existing symptom	Bony fragment (cm)	Incision	Operation	Gastroc-nemiusr ecession	F/U (Months)	Complica-tions	Outcomes
1. 1998, Maniscalco et al	1	32	M	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Excellent
	2	N/A	M	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Excellent
	3	N/A	M	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Excellent
	4	N/A	M	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Excellent
	5	N/A	F	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Excellent
	6	N/A	F	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Good
	7	62	F	N/A	N/A	Trauma	Yes	No	Posteromedial	3 Suture Anchors	No	6	No	Good
2. 2003, Bibbo et al	8	60	M	Mountain bike	None	Sport	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	11	No	AOFAS = 90
	9	66	F	Twisted ankle	Steroid for colon disease	Trauma	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	16	Ruptured Achilles proximal to initial repair	AOFAS = 100
	10	24	M	Basketball	None	Sport	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	60	No	AOFAS = 100
	11	44	F	Trip	DM, HNT	Trauma	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	4	No	AOFAS = 90
	12	52	M	Racquetball	Gunshot calcaneus	Sport	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	5.25	No	AOFAS = 100
	13	59	F	Fall	DM, Obesity	Trauma	Yes	N/A	Posteromedial	Trans-calcaneal Suture	No	5.5	Delay wound healing	AOFAS = 100
3. 2007, Dodd et al	14	42	F	Walking down the street	None	Trauma	No	No	Posteromedial	2 Suture Anchors	No	6	No	N/A
4. 2008, Lui et al	15	54	F	Chased a bus	N/A	Trauma	N/A	N/A	Posteromedial	2 Suture Anchors	No	N/A	N/A	N/A
5. 2014, Kilicoglu et al	16	31	N/A	Fall from height	None	Trauma	N/A	No	Midline	2 Suture Anchors	No	N/A	N/A	N/A
6. 2015, Yamaguchi et al	17	58	M	N/A	N/A	N/A	N/A	N/A	Midline	4 Suture Anchors with double Krackow suture	Yes	12	No	Japanese society for surgery of foot ankle/hindfoot scale = 95
	18	66	M	N/A	N/A	N/A	N/A	N/A	Midline	4 Suture Anchors with double Krackow suture	Yes	12	No	Japanese society for surgery of foot ankle/hindfoot scale = 85
	19	72	F	N/A	N/A	N/A	N/A	N/A	Midline	4 Suture Anchors with double Krackow suture	Yes	12	No	Japanese society for surgery of foot ankle/hindfoot scale = 87

Table 1. cont.

Year, Authors	No.	Age	Sex	Cause	Underlying diseases	Mechanism of injury	Pre-existing symptom	Bony fragment (cm)	Incision	Operation	Gastroc-nemiusr ecession	F/U (Months)	Complica-tions	Outcomes
	20	58	M	N/A	N/A	N/A	N/A	N/A	Midline	4 Suture Anchors with double Krackow suture	Yes	12	No	Japanese society for surgery of foot ankle/hindfoot scale = 94
7. 2016, Huh et al	21	45	M	Stepped in hole	DM, HTN, HLD	Trauma	Yes	1.2	Midline	2 Suture Anchors	No	83.5	No	VAS = 1, AOFAS = 90
	22	37	F	Aerobics	HTN	Sport	Yes	N/A	Midline	2 Suture Anchors	No	68.3	No	VAS = 0, AOFAS = 100
	23	40	M	Basketball	Leiomyo sarcoma	Sport	No	1.5	Midline	2 Suture Anchors	No	60.3	No	VAS = 0, AOFAS = 100
	24	63	M	Bird hunting	Gout	Trauma	Yes	0.6	Midline	2 Suture Anchors	No	53.0	No	VAS = 0, AOFAS = 100
	25	56	M	Deer hunting	Asthma, DM, HTN	Trauma	Yes	0.4	Midline	2 Suture Anchors	No	42.5	No	VAS = 7, AOFAS = 67
	26	32	M	Basketball	Gout	Sport	Yes	N/A	Midline	2 Suture Anchors	No	31.9	No	VAS = 1, AOFAS = 90
	27	56	M	Skiing	DM, HTN, HLD	Sport	No	0.6	Midline	2 Suture Anchors	No	28.5	No	VAS = 0, AOFAS = 95
	28	24	M	Basketball	None	Trauma	No	0.7	Midline	2 Suture Anchors	No	16.5	No	VAS = 1, AOFAS = 90
	29	51	M	Bicycling	None	Trauma	Yes	0.7	Midline	2 Suture Anchors	No	13.7	No	VAS = 0, AOFAS = 100
	30	40	M	Softball	HTN	Sport	Yes	2.5	Midline	2 Suture Anchors	No	12.6	Delay wound healingA	VAS = 0, OFAS = 95
	31	39	M	Basketball	None	Sport	Yes	1.1	Midline	2 Suture Anchors	No	12	No	VAS = 0, AOFAS = 94
8. Wakatsuki et al	32	64	M	Bicycling	None	Trauma	No	Yes, N/A	Midline	Trans-calcaneal Suture	No	24	No	Japanese society for surgery of foot ankle/hindfoot scale = 100

Table 1. cont.

Year, Authors	No.	Age	Sex	Cause	Underlying diseases	Mechanism of injury	Pre-existing symptom	Bony fragment (cm)	Incision	Operation	Gastroc-nemiusr ecession	F/U (Months)	Complica-tions	Outcomes
9. 2017, Rungprai et al	33	31	M	Basketball	None	Sport	Yes	1.0	Midline	4 Suture Anchors, SutureBridge	Yes	18	No	VAS = 0 , FAAM (ADL = 17 and Sport = 72, SF-36 (PCS = 50.5 and MCS = 55.9)
	34	60	M	Jump from ladder	Coronary heart disease	Trauma	Yes	0.5	Midline	4 Suture Anchors, SutureBridge	Yes	16	No	VAS = 0, FAAM (ADL = 30 and Sport = 70) , SF-36 (PCS = 55.2 and MCS = 56.7)
	35	56	M	Cortisone injection	None	Trauma	Yes	No	Midline	4 Suture Anchors, SutureBridge	Yes	14	No	VAS = 0 , FAAM (ADL = 30 and Sport = 69) , SF-36 (PCS = 51.7 and MCS = 54.3)
	36	60	M	Tennis	None	Sport	Yes	No	Midline	4 Suture Anchors, SutureBridge	Yes	12	No	VAS = 0 , FAAM (ADL = 30 and Sport = 66) , SF-36 (PCS = 52.8 and MCS = 59.8)

tendon rupture. Sleeve avulsion patients may present with symptoms similar to patients with a midsubstance tear; lateral foot radiographs and/or MRI can be helpful for diagnosing this condition. The standard treatment is to repair and attach the proximal stump of the Achilles tendon to the new footprint on the calcaneus. The double-row SutureBridge technique seems to be an effective technique which has demonstrated promising results with minimal complications.

What is already known on this topic?

Achilles tendon sleeve avulsion from its attachment to the calcaneus is a relatively rare condition compared to mid-substance Achilles tendon rupture. This type of rupture cannot be treated with conservative management. The standard surgical treatment is to reattach the proximal stump to the calcaneus. However, a variety of surgical techniques and methods of outcome measurement following this surgery are available. In addition, there is a paucity of reports of outcomes and complications following this surgery in the literature.

What this study adds?

The present study includes a case series of sleeve avulsion Achilles tendon rupture patients receiving a double-row SutureBridge technique with short- to intermediate-term follow-up for the entire cohort. A double-row SutureBridge configuration is a recently developed surgical technique which has been proven to be effective for reattaching the Achilles tendon to the calcaneus. We also provide validated outcome scores including Short-Form 36 [SF-36], Foot and Ankle Ability Measure [FAAM], and Visual Analogue Scale [VAS], as well as data on recovery time. Additionally, this study includes a review of related published literature that has never been accomplished before.

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Potential conflicts of interest

The authors declare no conflict of interest.

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