

## Original Article

# Reconstruction of combined defects of Achilles tendon and overlying soft tissues by tendon flap with descending genicular artery in children

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**Abstract:** The purpose of this study was to evaluate the efficacy and safety of tendon flap with descending genicular artery in reconstruction of combined defects of Achilles tendon and overlying soft tissues in children. Ten children with combined defects of Achilles tendon and overlying soft tissues were repaired by tendon flap anastomosed with descending genicular artery. Nine cases were repaired with adductor muscle tendon flap of descending genicular artery, and one case received gracilis tendon flap of descending genicular artery. The flap area ranged from 6 cm × 5 cm to 9 cm × 7 cm. Nine cases were treated with full-thickness skin graft of the lower abdomen, and the skin flap donor area was directly sutured in one child. Arterial embolism occurred in the flap of one child, which was diagnosed as vascular anastomotic embolism by reoperation. The flap survived after resection of the embolized vessels and re-anastomosis. The remaining 9 flaps survived and the donor site wounds were healed. During 6-36 months of follow-up (12 months on average), the heel skin flap was satisfactory in appearance, good in texture, and had 6-15 mm for two-point discrimination. The ankle function was fully recovered. The results of heel-rise test were negative. According to the American orthopedic foot and ankle society (AOFAS), the Ankle Hindfoot Scale scores were 86-100 points, with 97 points on average. Therefore, our results suggested that tendon flap with descending genicular artery was an efficacious and safe approach in the reconstruction of pediatric combined defects of Achilles tendon and overlying soft tissues, which can not only restore the heel function, but also enhance the appearance of the injured heel.

**Keywords:** Heel, defect, tendon flap, descending genicular artery, repair

## Introduction

The causes of pediatric combined defects of Achilles tendon and overlying soft tissues mainly include wheel wringing injury of bicycles or motorcycles. Reiss first described this kind of injury in 1948 [1] as 'spoke injury'. Most of the injuries involve heel skin and Achilles tendon defects. Comminuted calcaneal fracture is relatively rare, which can easily cause deep tissue infection. Therefore, it is not only required that the skin flap cover and protect deep tissues, but also the skin flaps are required to have certain sensitivity in repairing and reconstructing such injuries. Besides, the repaired Achilles tendon should have sufficient strength and tension [2, 3]. Suri *et al.* [4] have proposed the classification criteria and treatment principles as follows. Type I is mild soft tissue avulsion of

the heel, which can be debrided and sutured in one stage; Type II is defined as large soft tissue defects with avulsion but Achilles tendon exposure cannot be observed, and skin grafting is required. Type III is soft tissue avulsion combined with Achilles tendon injury and fracture, which can be treated by flap repair.

Bullocks *et al.* [5] have successfully applied sural fasciocutaneous flap to cover the wound surface of the heel, and the blood supply-preserved Achilles tendon V-Y was pushed forward to repair the Achilles tendon. Linton [6] has created a huge "V"-shaped incision at the back of the lower leg to move down the insertion of the medial and lateral ends of gastrocnemius muscle to repair the composite tissue defects at the heel. Arslan *et al.* [7] have applied the peroneal artery flap of the leg to cover the wound sur-

face, while Achilles tendon reconstruction is replaced by allogeneic Achilles tendon. Haas [8] applied free lateral upper arm flap to cover the wound surface. The reconstruction of Achilles tendon was performed with free fascia lata instead of repair. Taniguchi *et al.* [9] have used medial plantar flap to cover the wound surface and freed fascia lata to replace Achilles tendon. Animal studies have confirmed that the adhesion degree with blood supply in the tendon transplantation group is less than that in the free tendon transplantation group [10]. Silver [11] has studied that transposition of fibular long and short tendons can cause imbalance of foot varus muscle strength, which should be used with caution for children and adolescents. Taylor *et al.* [12] first utilized free composite tissues to repair the combined defects of heel in one stage surgery in 1979. Deiler [13] *et al.* have conducted a comparative study on repairing the defect of compound tissue in the heel region with or without lateral femoral skin flap and fascia lata compound tissues. The functional recovery of the heel region repaired by the neurovascular flap is more satisfactory.

In this study, the lower limb specimens perfused with red latex through the femoral artery were conducted and observed. A tendon flap anastomosed with the descending genicular artery was designed and established to repair the combined defects of Achilles tendon and overlying soft tissues in 10 children and the clinical efficacy and safety were assessed during long-term follow-up.

### Case report

#### Baseline data

There were 7 male and 3 female children in our study and their average age was 9 years old. All cases were caused by motorcycle wheels twist. Seven cases were heel soft tissue defects complicated with Achilles tendon defects, calcaneal partial defects and Achilles tendon insertional avulsion. Three cases were diagnosed as heel soft tissue defects with Achilles tendon defects. The residual Achilles tendon was approximately 1.0 cm and the length of Achilles tendon defect was 3-7 cm in length. One case suffered from open talocalcaneal joint, and the skin defect area ranged from 5 cm × 4 cm to 8 cm × 7 cm. Emergency debridement was carried out in the

first stage, followed by performing sub-emergency repair operation in the second stage. The repair time from injury to the second stage operation was 7-22 d, with 11 d on average. Nine cases were repaired with adductor muscle tendon flap of descending genicular artery, and 1 case was repaired with gracilis tendon flap of descending genicular artery. The skin flap donor area was treated with full-thickness skin graft of the lower abdomen in 9 cases, and the skin flap donor area was directly sutured in the remaining 1 child.

#### Case 1

On November 1, 2006, a 7-year-old boy was admitted to the emergency department due to partial skin and soft tissue defects in the right heel caused by the rear wheel strangulation of the motorcycle. On admission, skin and soft tissue defects with an area of approximately 4.0 cm × 5.0 cm was found on the right heel and posterior malleolus with uneven wound margins. Most defects at the Achilles tendon insertion point were seen on the wound surface with approximately 3.5 cm in length, and cortical defects were observed at the calcaneus of Achilles tendon insertion. Evident swelling was seen in the middle and lower legs. The right foot was injured with active bleeding and limited in walking, and the wound surface was seriously contaminated (**Figure 1A, 1B**). Wound debridement and local flap transfer to cover the right heel wound were performed. At postoperative 3 weeks, the boundaries between skin bruises on the right heel and Achilles tendon necrosis were clear. After preoperative preparation, resection and expansion of necrotic tissue of the right foot, repair of wound surface and Achilles tendon with free gracilis tendon flap of left descending genicular artery, and reconstruction of Achilles tendon insertion point were carried out under intravenous general anesthesia on November 22, 2006. The residual wound area of the right heel was approximately 5.0 cm × 6.0 cm, and the length of Achilles tendon defect was about 4.5 cm in length. Vascular nerves in the recipient area were exposed and marked. The descending genicular artery tendon flap was designed on the medial proximal end of the left lower leg with medial malleolus and medial femoral condyle midline as axes. The axis of the flap was determined based on the shape of the



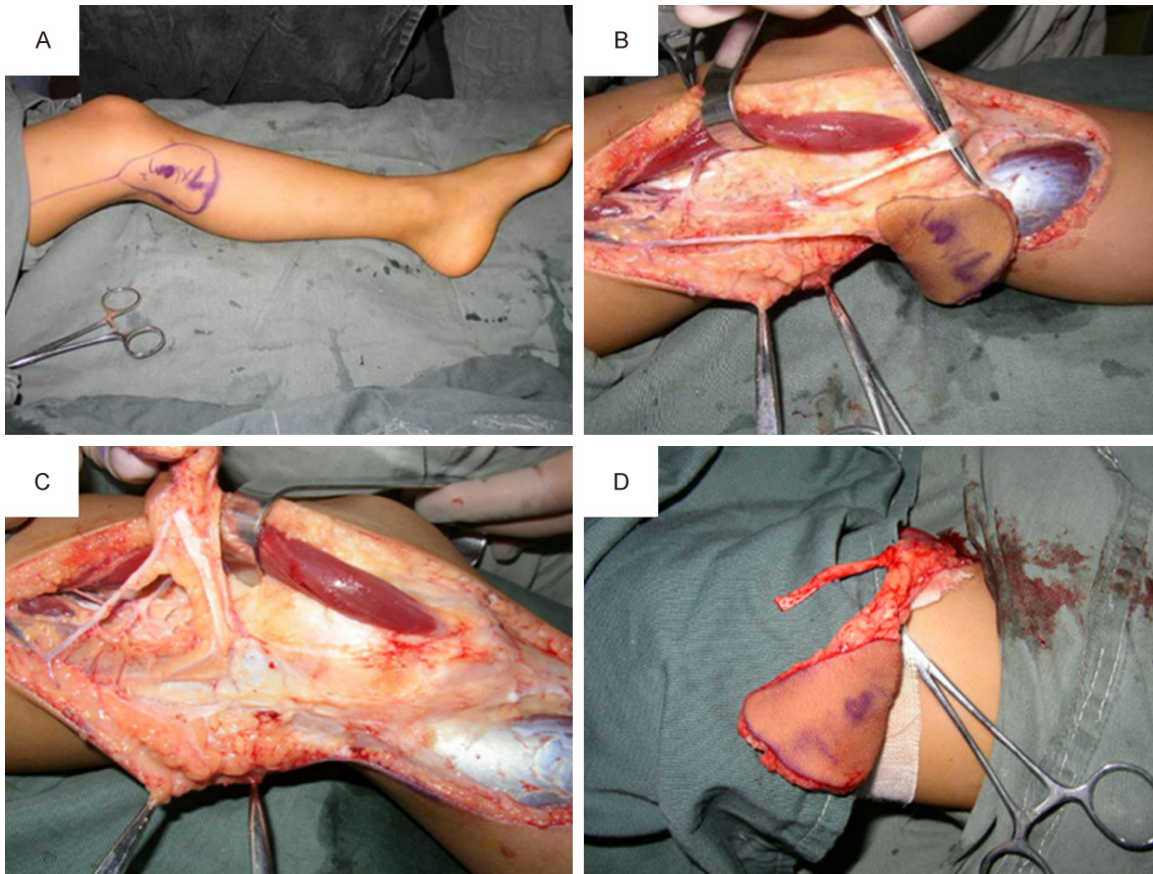
**Figure 1.** Skin defects of right heel accompanied by large skin scratch of lower leg (A), partial calcaneal abrasion at Achilles tendon insertion (B), right heel skin and Achilles tendon necrosis at 3 weeks after debridement (C), clear boundaries of skin necrosis, wound size of necrotic tissue resection, length of Achilles tendon defects and vascular nerve exposure in recipient region (D).

descending genicular artery saphenous artery. The flap area was 7 cm × 6 cm (**Figure 1C, 1D**). The proximal end of the flap was incised to find the saphenous nerve and saphenous artery on the deep surface of the great saphenous vein. The distal great saphenous vein was cut off and ligated at the distal end of the flap. The flap was cut off in the deep layer of the deep fascia. The gracilis tendon along with the aponeurosis were resected to protect the branch of the descending genicular artery into the aponeurosis. The gracilis tendon was cut to 5 cm to form a compound tissue flap pedicled with gracilis tendon and descending genicular artery (**Figure 2**). The pedicle of the flap was severed after 10-min blood circulation, and then transferred to the recipient area. The flap was fixed by simple suture with several needles surrounding the wound surface. The calcaneus at the Achilles tendon insertion was perforated. The tendon of gracilis muscle was tightly attached to the calcaneus at the insertion by Bunnel wire extrac-

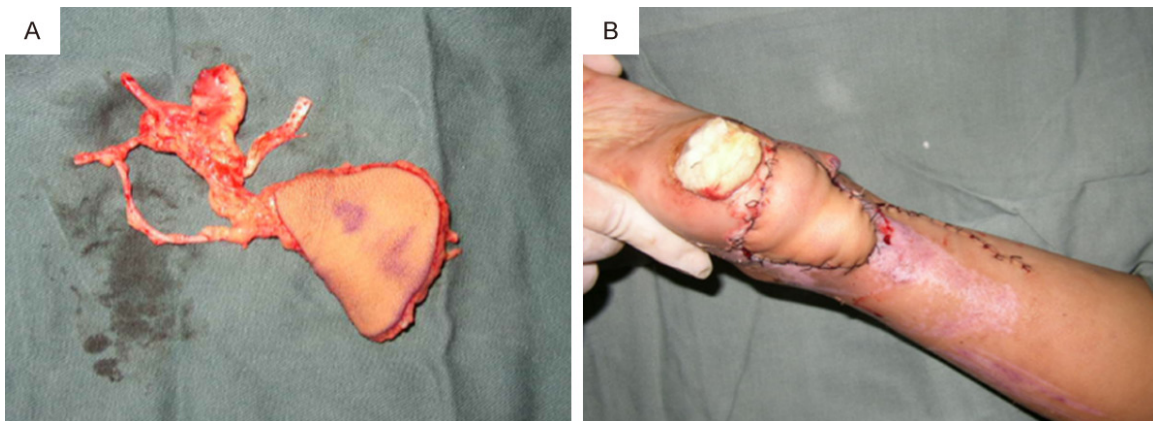
tion method. The tendon was sutured with the residual periosteum and Achilles tendon by line 7. After the ankle joint was placed in the neutral position, the tension of Achilles tendon was adjusted, and the proximal end of tendon in the flap was anastomosed with the proximal end of Achilles tendon by “8”-shaped suturing method. After further debridement under the microscope, the branches of small vessels were ligated carefully. The inferior genicular artery and the accompanying vein were anastomosed with the posterior tibial artery and the accompanying vein at the inner end of the flap. The great saphenous vein skin flap was anastomosed at the end of the great saphenous vein, the great saphenous nerve skin flap was anastomosed at the end of the great saphenous nerve, and the edge of the flap was sutured (**Figure 3**). Full-thickness skin graft was obtained from the right lower abdomen. Anti-infection, anti-vasospasm and anti-coagulation treatment were given after the operation.



Achilles tendon and overlying soft tissues by tendon flap with descending genicular artery



**Figure 2.** The left descending genicular artery tendon flap is designed at the medial proximal end of the lower leg (A), exposure of nutrient vessels in various tissues of descending genicular artery tendon flap (B); deep side of descending genicular artery tendon flap (C); descending genicular artery tendon flap preserving artery and vein, and the skin color was ruddy (D).



**Figure 3.** Tendon flap of descending genicular artery after incising pedicle (A); the blood flow of the flap was normal after the repair of descending genicular artery tendon flap (B).

On December 20, 2006, the extractable steel wire reconstructed at Achilles tendon insertion was removed and the child was successfully discharged (**Figure 4A, 4B**). Following up for 3

years until December 25, 2009, the flaps survived well with good shape and texture. No wound ulceration occurred, the skin flap was sensitive in pain, temperature, touch and two-



**Figure 4.** The shape of descending genicular artery tendon flap at 4 weeks after operation (A); survival of tendon flap donor site at 4 weeks after skin grafting (B); active dorsiflexion activity of right ankle joint at postoperative 3 years (C); active plantar flexion activity of right ankle joint at 3 years after operation (D).

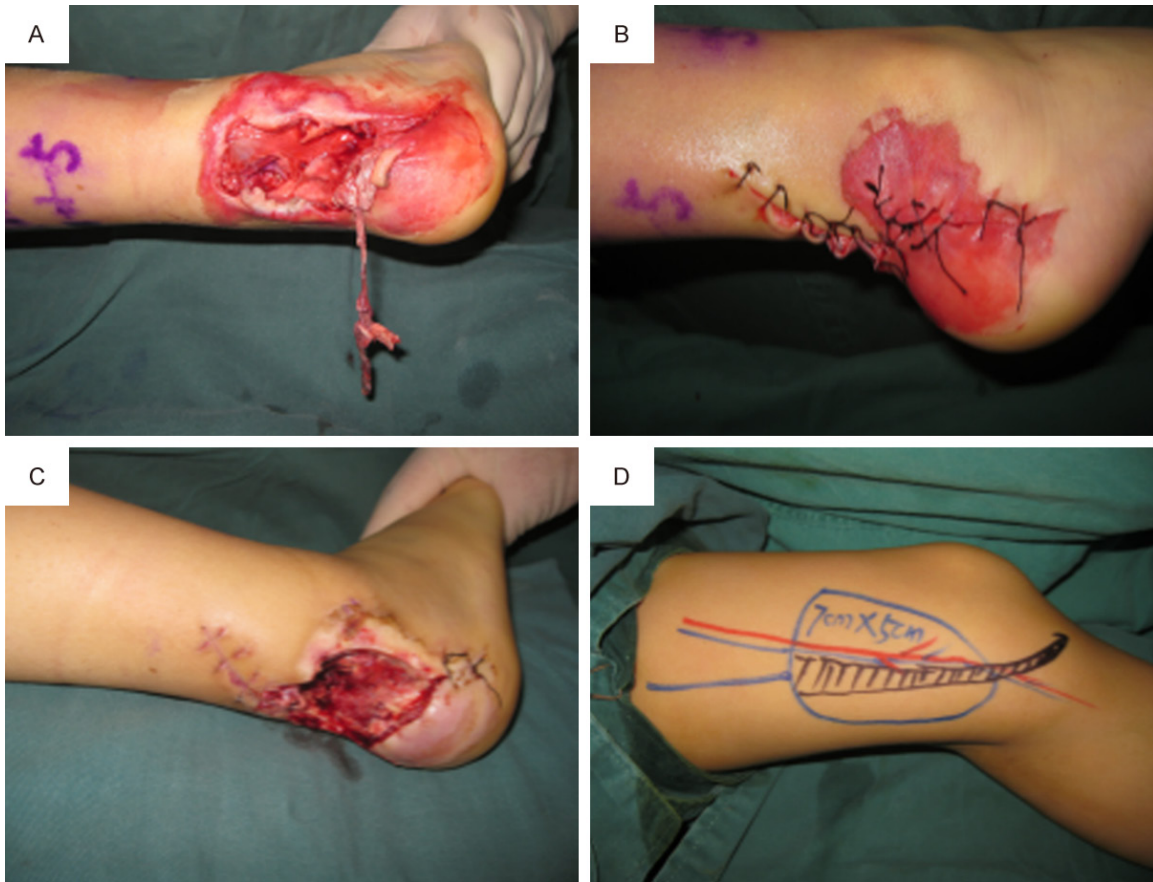
point discrimination test, and the right ankle joint and hind foot normally functioned (**Figure 4C, 4D**).

#### Case 2

A boy, aged 7 years, was admitted due to partial skin and soft tissue defects caused by a motorcycle wheel strangulation on his right heel on January 05, 2011. The skin and soft tissue defects were measured 5.0 cm × 4.5 cm with uneven wound margin. Achilles tendon rupture and posterior ankle joint capsule rupture were noted on the wound surface. The Achilles tendon defect was about 3.5 cm, severe skin contusion around the wound margin was 3.0 cm, and the wound margin had skin scratches of different degrees. Debridement of the right heel wound, repair of the ankle joint capsule, posterior tibial artery nerve exploration, and local skin flap repair were performed immediately after admission (**Figure 5A, 5B**). At 16 d after operation, bruised skin with clear necrosis boundary was seen and partial necro-

sis was detected in the Achilles tendon. Resection and expansion of necrotic tissues, repair of wound surface and Achilles tendon with adductor muscle tendon flap of left descending genicular artery, reconstruction of Achilles tendon insertion were performed under general anesthesia. After removing necrotic skin and Achilles tendon during the operation and expanding the wound, the residual wound on the right heel was about 6.0 cm × 4.5 cm, and the defect at the broken end of Achilles tendon was 4 cm. The vascular nerves in the recipient area were exposed and marked. A sample cloth was trimmed according to the size of the wound in the recipient area and appropriately enlarged on the distal end of the inner side of the left thigh with the medial midline of the thigh as the axis. A longitudinal incision was created along the medial thigh at the proximal end of the flap, the skin and subcutaneous fascia was incised, the descending genicular artery and saphenous artery were separated and dissected, and the great saphenous vein and medial thigh cutaneous nerve were dis-

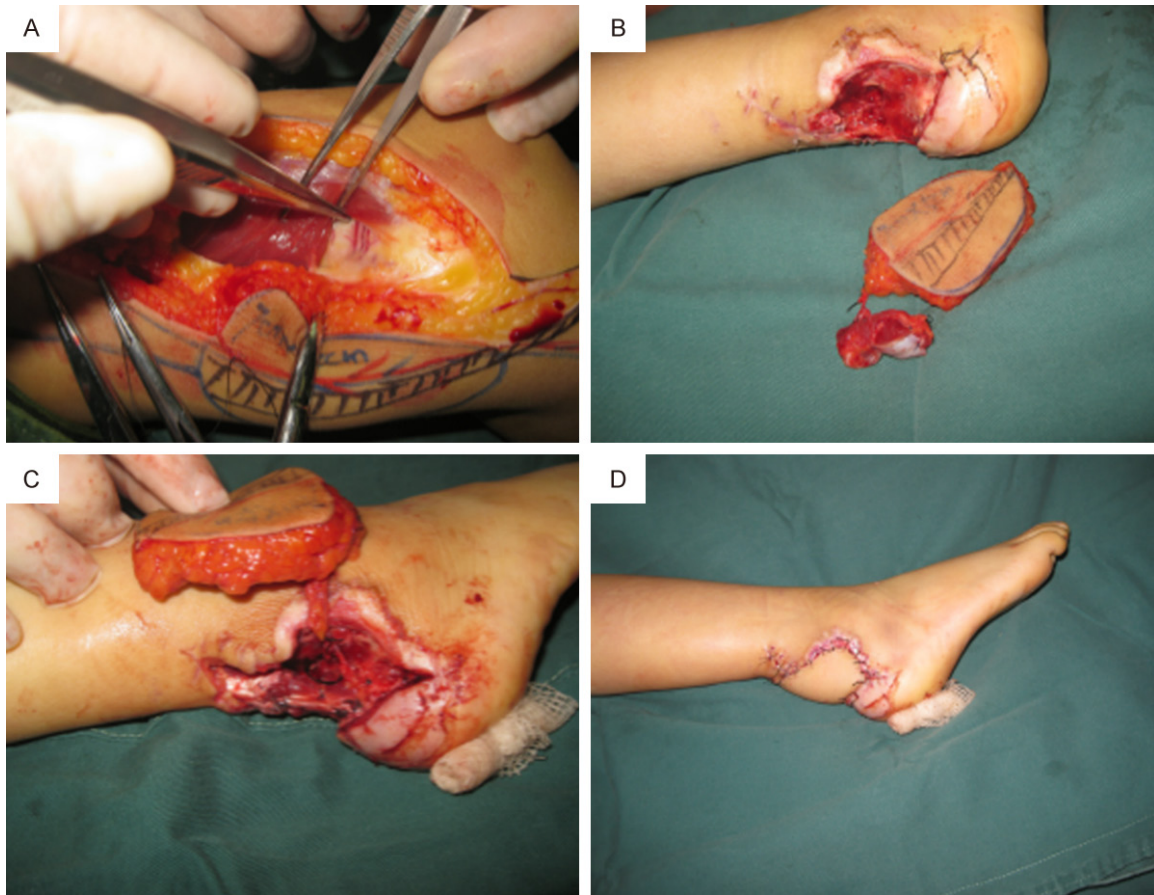




**Figure 5.** Skin defect of right heel and skin scratch (A); emergency debridement of the right heel and local skin flap covering the wound (B); partial necrosis of the bruised skin on the right heel at 16 days after debridement, skin and Achilles tendon defects after resection and expansion of necrotic tissue marked with vascular nerve in the affected area (C); design of tendon flap of distal descending genicular artery on medial left thigh (D).

sected after entering the adductor muscle tendon branch, and the flap was dissected at the deep fascia layer after identifying the cutaneous branch. Then, the distal end of the flap was cut off, the distal saphenous vein was cut off and ligated, and the adductor muscle tendon was incised along with the aponeurosis to protect the branch of descending genicular artery entering aponeurosis. The length of adductor muscle tendon was 5 cm. A composite tissue flap with adductor muscle tendon and skin pedicled with descending genicular artery was constructed (Figure 5C, 5D). After bleeding for 10 min, the pedicle of the skin flap was cut off and transferred to the recipient area. Simple suture and fixation were performed around the wound surface. The calcaneus was perforated at the Achilles tendon insertion. The adductor muscle tendon was tightly attached to the calcaneus at the insertion point by Bunnell steel wire extraction method, and sutured with the residual peri-

osteum and Achilles tendon by line 7. After the ankle joint was placed in the neutral position, the tension of Achilles tendon was adjusted, and the proximal end of tendon in the flap was anastomosed with the proximal end of Achilles tendon by Kessler suture method. Further debridement was carried out under a microscope. The descending genicular artery and accompanying vein in the flap were anastomosed end to end with the posterior tibial artery and accompanying vein in the recipient area. The great saphenous vein in the flap was anastomosed end to end with the great saphenous vein. The medial thigh cutaneous nerve in the flap was anastomosed end to end with the saphenous nerve in the recipient area. The flap edge was sutured. When the tourniquet was relaxed, the flap turned ruddy and the donor area of the flap was directly sutured (Figure 6). Anti-infection, anti-vasospasm and anti-coagulation treatment were delivered post-



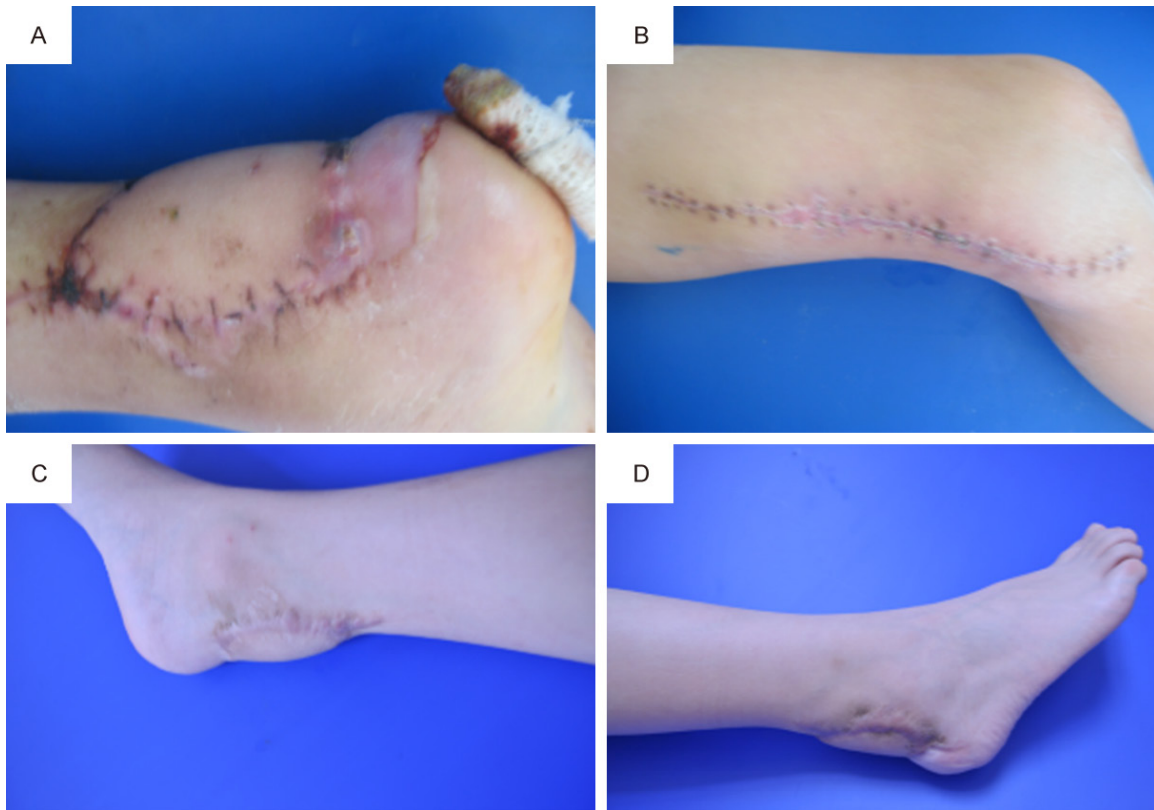
**Figure 6.** Exposure of tendon and blood vessels of descending genicular artery tendon flap (A); descending genicular artery tendon flap was transferred to recipient area (B); repair of Achilles tendon with greater tendon and reconstruction of Achilles tendon insertion (C); shape of right heel after repair with descending genicular artery tendon flap (D).

operatively. The patient recovered smoothly and was discharged on February 15, 2011 (Figure 7). During the 17-month follow-up, the right foot flap survived well in good shape and texture. No ulcer occurred in the heel, and the heel was sensitive to pain, temperature, touch and two-point discrimination. The right ankle joint and hind foot activities were normal, and the heel-rise test yielded negative outcomes (Figure 8).

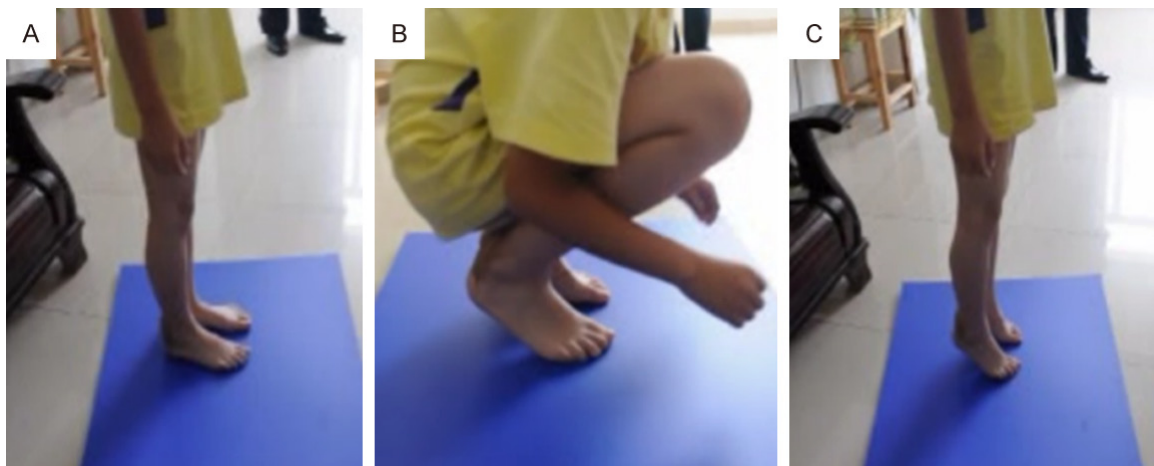
#### Discussion

The advantages of tendon flap with descending genicular artery are as follows. First, the flap is flexible in design and has a wide range of repair. The flap can be designed at the distal inner thigh or proximal inner leg according to the skin defect of Achilles tendon and heel in the recipient area. As tendon skin flap or bone tendon skin flap, the repair of Achilles tendon and heel skin and soft tissue defect and reconstruction

of Achilles tendon insertion point can be completed in one stage operation. Second, the obtained tendons and bone slices are supplied with blood and are benefited by Achilles tendon healing, tensile strength and abrasion resistance. Third, the gracilis muscle or adductor muscle tendon is relatively superficial, close to the skin flap and relatively easy to dissect. Fourth, the flap is abundant in sensory nerves, which can reconstruct the sensation of the heel. Fifth, the skin flap is thin and soft with slight subcutaneous fat and beautiful in appearance. Sixth, the flap contains two sets of deep and shallow venous reflux systems. After repair, the flap, which has good reflux, is not prone to venous crisis and is likely to survive. Finally, the donor site is slightly damaged without compromising the main artery of the lower limb, which does not affect the blood supply of the lower limb or the muscle strength of the lower limb. Nevertheless, there are several disadvantages of this technique which should be



**Figure 7.** Appearance of the heel at 25 days after repair with descending genicular artery tendon flap (A); healing of descending genicular artery tendon flap in the donor site (B); the medial side of the right heel at postoperative 17 months (C); the lateral side of the right heel at postoperative 17 months (D).



**Figure 8.** Standing on right foot (A); right ankle dorsiflexion activity (B); right heel-rise test (C) at 17 months after operation.

acknowledged. First, the donor area is relatively evident and likely to be exposed. Second, the saphenous nerve which is cut from the donor site of the flap exerts certain influence on the sensation of the medial leg and the medial foot, but the sensation will be compensated after

long-term follow-up. Third, it takes a long time and is difficult to dissect and protect multiple composite tissues when cutting bone flap carrying tendon. Fourth, when the adductor muscle tendon is short and the Achilles tendon defect is long, a certain amount of muscle



should be collected. Last, a long segment can be incised and folded for repair when the Achilles tendon defect is short.

Because the great saphenous vein is contained in the flap, the deep vein function should be assessed before operation. For patients with deep venous insufficiency, the venous reflux of lower limbs will be affected. Therefore, this operation should be performed with caution. In addition, the saphenous branch and articular branch blood vessels should not be dissected and separated deliberately when the vascular pedicle is removed intraoperatively to prevent the nutrient vessels of cutaneous branch or tendon branch from being damaged. When cutting the skin flap, the complete deep and shallow fascia should be included, because the deep fascia contains rich vascular network. The skin of the superficial fascia and pedicle should be preserved as much as possible. It is of significance for the survival of the distal end of the skin flap to retain more cutaneous branch vessels. Both sets of venous reflux are reconstructed to facilitate the reflux of flap. The internal artery of the flap is anastomosed with the posterior tibial artery in the recipient area. Prior to operation, whether the anterior tibial artery in the recipient area is damaged should be evaluated to avoid the incidence of insufficient blood supply to the limbs.

After the repair of tendon flap anastomosed with descending genicular artery, plaster is used to fix ankle joint in a neutral position. Plaster is removed in the 3<sup>rd</sup> to 4<sup>th</sup> week. If there is internal fixation or reconstruction of Achilles tendon insertion, internal fixation is removed in the 4<sup>th</sup> to 6<sup>th</sup> week, and ankle joint protective brace is worn to walk gradually with load. Bracket is removed in the 7<sup>th</sup> to 8<sup>th</sup> week, and ankle joint function exercise and heel-rise exercise are gradually strengthened. In this study, 1 case suffered from open tibialis calcaneus joint and Achilles tendon insertional defects. The functional exercise with a brace was not started until 6 weeks after plaster fixation. During subsequent follow-up, the ankle joint extension and flexion and various activity scores were slightly lower. Therefore, early postoperative rehabilitation training may accelerate the functional recovery.

A simple classification system [14] has been proposed to evaluate the clinical efficacy of

Achilles tendon repair. Nevertheless, the evaluation method is relatively simple and not comprehensive. The composite tissue defects of the heel affect the Achilles tendon, peritendinous skin, calcaneus and even ankle joint injury. Repair and reconstruction are involved with various tissues, such as skin flap, tendon and bone. Functional evaluation of a single tissue cannot fully reflect the overall surgical effect. In this clinical trial, a flap evaluation standard combined with an ankle and hind foot scoring system were adopted to comprehensively evaluate the postoperative efficacy. Although the evaluation was relatively comprehensive, the results may be subject to subjective consciousness due to lack of sufficient objective parameters.

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#### Disclosure of conflict of interest

None.

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