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Step-advanced rectangular flap

A novel technique for the reconstruction of soft-tissue defects overlying the Achilles tendon in children (an observational study)

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Abstract

Soft-tissue defects overlying the Achilles tendon are common complications after bicycle or motorcycle spoke injuries in children and usually require surgical management by various flaps. There is no apparent consensus on the optimal choice of flaps for these injuries. We designed a novel step-advanced rectangular flap to reconstruct small to moderate soft-tissue defects around the Achilles tendon. This study was performed to review our experience and evaluate the clinical effectiveness of the step-advanced rectangular flap.

From May, 2014 to September, 2016, 12 consecutive children with soft-tissue defects overlying the Achilles tendon caused by spoke injuries were treated with the step-advanced rectangular flap. The patients' general information, surgical details, and postoperative complications were recorded. The Mazur evaluation system was used to assess clinical outcomes.

All patients were followed up for ≥12 months (range 12–38 months). All flaps survived completely. Superficial infection occurred in 2 patients and healed by second intention after dressing changes; the other patients' surgical wounds healed by primary intention. The scars around the flaps in 2 patients were remarkable, and all others showed good results in terms of flap color and texture. Ankle function was normal, and satisfactory results were obtained in all cases. According to the Mazur evaluation system, the results were excellent in 9 patients and good in 3, with an excellent and good rate of 100% at 12 months postoperatively.

The rectangular advancement flap appears to be a simple and reliable method for small to moderate soft tissue defects overlying the Achilles tendon in children.

Abbreviations: K-wire = Kirschner wire, V-Y advancement flap = V-shaped and Y-shaped advancement flap.

Keywords: Achilles tendon, child, soft-tissue reconstruction, surgical flaps

1. Introduction

Spoke injuries usually result from the rear wheel spokes of a bicycle or motorcycle, and were first reported by Reiss in 1948.[1] Since then, many reports of spoke injuries have been published.[1,2] Spoke injuries commonly affect the heel region in children, resulting in Achilles tendon exposure or rupture with or without calcaneal fracture or defects. Even a small soft-tissue defect overlying the Achilles region still presents a challenge for plastic and orthopedic surgeons, and requires flap transfer for reconstruction because of the repeated friction from footwear.[3] Thus, several flaps have been recommended as the treatment of choice, including the posterior tibial artery perforator flap, posterior supramalleolar flap, V-shaped and Y-shaped advancement flap (V-Y advancement flap) of the posterior heel, and lateral calcaneal artery perforator-based skin flap.[3–6] However, these flaps are frequently associated with a prolonged operating time, require microsurgical expertise, and induce significant donor-site morbidity.[3,7] For these reasons, we designed a novel step-advanced rectangular flap to reconstruct small to moderate soft-tissue defects around the Achilles tendon in children. This flap can be harvested quickly and easily. It also provides like-for-like tissue reconstruction in terms of color, texture, and thickness without significant donor-site morbidity.[3] We herein share early our experience with 12 patients who successfully underwent this novel surgical method.

2. Patients and methods

2.1. Inclusion and exclusion criteria

The inclusion criteria for this study were an age of ≤8 years, soft-tissue defects located at the heel and combined with Achilles tendon exposure, heel injury as the cause of the post-traumatic defects, and a soft tissue defect size of $<5.5\,\text{cm} \times 4.0\,\text{cm}$. The exclusion criteria were larger defects, trauma caused by incidents

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Table 1

Clinical characteristics, follow-up period, and function score of patients.

Patient	Sex	Age (y)	Cause of injury	Side of injury	Size of defect (cm × cm)	Duration of surgery (min)	Time to heal (wks)	Follow-up period (mos)	Mazur score	Complication
1	M	3	Electrombile rear wheel	Left	4.2 × 3.6	30	2	38	100	No
2	W	2	Bicycle rear wheel	Right	3.7 × 3.0	45	2	16	100	No
3	M	2	Bicycle rear wheel	Right	3.6 × 3.0	25	2	34	100	No
4	W	7	Motorcycle rear wheel	Right	5.5 × 4.0	30	2	21	97	No
5	M	2	Bicycle rear wheel	Left	3.4 × 2.7	35	4	12	86	Superficial infection
6	W	8	Electrombile rear wheel	Right	4.5 × 3.6	42	2	12	87	No
7	M	5	Electrombile rear wheel	Left	4.2 × 3.9	40	2	19	100	No
8	M	6	Electrombile rear wheel	Left	4.8 × 3.3	38	2	28	94	No
9	W	4	Bicycle spoke injuries	Left	3.8 × 3.5	30	2	38	100	No
10	M	6	Motorcycle rear wheel	Right	5.0 × 4.0	36	4	16	87	Superficial infection
11	M	3	Bicycle rear wheel	Right	4.0 × 2.9	40	2	22	100	No
12	M	5	Electrombile rear wheel	Left	4.6 × 3.3	35	2	31	93	No

other than spoke injuries, and accompanied by lateral defects or bruising in flap area.

2.2. General information

From May, 2014 to September, 2016, 12 consecutive children (8 male and 4 female) who were admitted to our orthopedic center were included in the study. The mean age of the patients was 4.4 years (range 2–8 years). All patient injuries were caused by rear wheel spokes and comprised 5 cases of electromobile spoke injuries, 5 cases of bicycle spoke injuries, and 2 cases of motorcycle accidents. The skin defects were on the right side in 6 patients and on the left side in 6 patients. According to the classification of spoke injury by Zhu,[1] all cases were type I injuries. The patient details are summarized in Table 1.

The study was approved by the hospital ethics committee, and all patients or their guardians provided written informed consent.

2.3. Surgery techniques

The step-advanced rectangular flap was used for reconstruction of the soft-tissue defects overlying the Achilles tendon. We first evaluated the size of the defects to determine whether the flaps are suitable for reconstruction. The surgical procedure was performed in the lateral position under general anesthesia or epidural anesthesia. A pneumatic tourniquet was cautiously placed around the upper thigh to prevent bleeding during the procedure. Typical treatment strategies included radical debridement and subsequent flap grafting.

First, all contaminated and necrotic soft tissue was radically debrided. If the Achilles tendon was partly ruptured, reconstruction was performed by suturing. Importantly, the integrity of the Achilles tendon was preserved as much as possible. Fortunately, no patients had an entire rupture of the Achilles tendon. After debridement, the area of the soft-tissue defect was measured with the ankle joint in the neutral position. The area of the defect ranged from 3.4 cm × 2.7 cm to 5.5 cm × 4.0 cm.

Two longitudinal incisions were created along both sides of the soft-tissue defect from the proximal margin of the defect to the proximal aspect of the Achilles tendon. The incisions were parallel to each other and reached the superficial layer of the Achilles tendon membrane. The length of the incisions was made 1 to 1.5 times as long as the longitudinal length of the skin defect. The flap was dissected to the proximal end of the incisions along the paratenon membrane surface of the Achilles tendon, and a rectangular flap was developed. The flap was step-advanced distally to cover the soft-tissue defect overlying the Achilles tendon with the ankle joint in maximum plantar flexion. We ensured that the length of the flap was adequate to prevent excessive tension when the flap was repositioned. If excessive tension existed, the pedicle of the flap was extended. The length of the flaps varied from 3.8 to 6.5 cm (average 5.2 cm), and the width varied from 2.7 to 4 cm (average 3.4 cm). A 1.5-mm Kirschner wire (K-wire) was then applied from the planta pedis to the tibia to immobilize the ankle joint in plantar flexion, and the extent of plantar flexion was dependent upon the distal blood supply of the flap. The distal edge of the flap was sutured; then both sides were sutured. After surgery, immobilization of the ankle joint was strengthened with a plaster splint to prevent the K-wire from bending (Fig. 1).

The flap was monitored every 2 hours during the first 36 hours. Clinical parameters including skin color, capillary refill time, and skin temperature were evaluated. All patients received intravenous cephalosporin as antibiotic therapy immediately after debridement and continuing for 3 days. The sutures were removed about 2 weeks postoperatively, when the incision had healed. In all patients, the ankle was immobilized with a dorsal plaster splint to keep the ankle joint in plantar flexion for 3 to 6 weeks; the K-wire and plaster splint were then removed, and the patients began walking and moving the ankle joint. The Mazur evaluation system was used to assess clinical outcomes, including pain, function, and the range of motion of the ankle joint on their last follow-up 1 year postoperatively.[8]

2.4. Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

3. Results

All patients were followed up for ≥12 months (range 12–38 months). All flaps survived, and no flap necrosis was observed except in 2 patients who developed a small superficial infection at the distal edge of the flaps. The infection in both patients healed

Figure 1. Case 4: a 7-year-old girl sustained a spoke injury on the right heel by the rear wheel of a motorcycle. (A) The wound became infected 1 week after the injury. (B) The size of the soft tissue defect on the right heel was 5.5 cm × 4.0 cm after debridement and was combined with a partial rupture of the Achilles tendon and a calcaneal defect. (C) Two straight 6.5-cm-long incisions were made proximally on both sides of the skin defect, parallel to the Achilles tendon. (D) A rectangular flap was developed after dissection to the proximal end of the incisions, and the paratenon membrane surface of the Achilles tendon was revealed. (E) The ankle joint was immobilized by a 1.5-mm K-wire in plantar flexion, and the flap was advanced distally to cover the skin defect area. The flap survived well for 2 weeks postoperatively, at which point the stitches were removed. The plaster splint and K-wire were removed at 6 weeks postoperatively, and the patient started to walk and squat. (F–J) At the 1-year follow-up, the patient had a satisfactory aesthetic and functional outcome.

by dressing changes every 2 days, for 2 weeks. All patient injuries healed successfully, and no ankle joint stiffness was observed in any case. All patients were able to walk and squat normally 1 to 2 months after removing the plaster splint, and no problems occurred while wearing footwear. All patients had a satisfactory aesthetic outcome. In 4 of the 12 patients, the ankle joint was immobilized with a plaster splint and K-wire in plantar flexion for 3 weeks, whereas the ankle joint of the other 8 patients was immobilized for 6 weeks. At 6 months postoperatively, the cosmetic result was better with a smaller linear scar in the patients who had undergone longer immobilization. According to the Mazur evaluation system,[8] the results were excellent in 9 patients and good in 3, with an excellent and good rate of 100% at 12 months postoperatively.

4. Discussion

The soft-tissue defects overlying the Achilles tendon are quite common.[9] Once they occur, the reconstructing pose a surgical challenge to the reconstructive surgeons because the healing potential in this area with poorer blood supply is weak.[4,10,11] Simultaneously, the posterior heel has a high requirement to the soft tissue for cover involving having a good wear resistance and sensation for repeated friction by footwear.[5,11] There are many reconstructive techniques reported to date for this region, including split thickness skin grafts, reverse sural flap, antero-lateral thigh free flap, posterior tibial artery perforator flaps, lateral calcaneal artery flap, and so on.[3,6,12–14] The drawbacks and problems with those flaps encountered the donor site required skin grafting at the donor site, a poor cosmetic appearance due to bulky dimensions of the flap, sensory disturbance, and major arteries sacrificed.[3,6,10,12–14] However, it is not necessary for small to moderate-sized defects to select those flaps which have significant donor site and receptor complications. Some local flaps have been described and designed, involving V-Y advancement flap and bipedicled flap.[4,5,7] Maruyama et al[4] reported on the successful use of a V-Y advancement flap for the reconstruction of skin defects of the posterior heel and ankle. Lin et al[7] reported that the 11 patients underwent bipedicled fasciocutaneous flap placement to resurface the complex soft-tissue defects for the exposed Achilles tendon. Their results were excellent.[4,5,7] We improved and designed the step-advanced rectangular flap which further reduced the surgical trauma and operation time. The step-advanced rectangular flap had a good durability and sensation because of its repairs by tissue expansion.[15]

4.1. Advantages and disadvantages of step-advanced rectangular flap

Soft-tissue defects overlying the heel region with Achilles tendon exposure are usually repaired with various flaps, each of which

Figure 2. (A) A metal wire mesh is equipped to strengthen the spoke guards. (B) The wire mesh can effectively prevent the child feet from being entrapped between spokes through the frame gaps.

has different advantages and disadvantages. Our flap has several advantages. First, harvesting of a step-advanced rectangular flap is relatively quick and easy, taking only 25 to 40 minutes. Dissection of artery perforators is unnecessary, and the survival rate of the flap is high. A cadaver study indicated that the blood supply around the Achilles tendon in the heel zone mainly depends on the perforators of the posterior tibial artery and peroneal artery, and these perforators form 2 longitudinal chains adjacent to the subcutaneous tissue and Achilles tendon. These chains anastomose superiorly with the perforators of the middle zone, which can provide a good blood supply for the rectangular advancement flap.[16] Second, the skin texture of the flap is very soft, the flap is thick, and it has good wear resistance, making extra skin grafting unnecessary, and the skin grafting is not required at the donor site.

Although the step-advanced rectangular flap can provide reliable reconstruction for soft-tissue defects overlying the Achilles tendon, not all patients are suitable candidates because of the limited length-to-width ratio of the flap. The largest defect area in our study was 5.5 cm × 4.0 cm, and the flap could only be advanced distally about 2 cm. Thus, we recommend the step-advanced rectangular flap to reconstruct small-to-moderate defects, because we have no experience regarding whether the flap is suitable for larger soft-tissue defects overlying the heel. Moreover, it is not a suitable flap when the soft-tissue defect is located on the lateral sides of the Achilles tendon or a contusion is present in the skin proximal to the defect. The ankle joint should be immobilized in plantar flexion using a plaster splint and K-wire to decrease the tension of the flap for 6 weeks. Because the children cannot keep their limbs still, the use of a plaster splint and K-wire is encouraged to increase the blood supply to the region.[9] In our experience, the appearance of the linear scar was more obvious when plaster splint immobilization was performed for <3 weeks. The patients in our study were young, with an average age of 4.4 years (range 2–8 years); we have no experience regarding whether this flap is suitable for older children.

4.2. Intraoperative considerations

Spoke injuries in children frequently lead to skin laceration and contusion, and it is sometimes difficult to identify the injury boundary after initial debridement. In our study, initial debridement was performed in 3 patients as an emergency operation, and a second debridement was performed 5 to 7 days later; the defect was simultaneously repaired with the rectangle flap at that time. The lateral incision should be performed layer by layer, and the sural nerve should be freed and protected once it has been reached. We have no experience regarding whether the flap is suitable for patients whose Achilles tendon has completely ruptured or avulsed from the calcaneus tubercle. The ankle joint should be immobilized in plantar flexion to decrease the flap tension. The degree of plantar flexion differs from patient to patient depending on the blood supply of the distal flap. Because children often do not cooperate well, a K-wire alone cannot maintain the ankle joint in plantar flexion, and a plantar splint must be used to strengthen the immobilization.

Best techniques is inferior to early prevention, so we recommend that every bicycle or motorcycle must be equipped with effective and good guards for back spoke when the pillion passenger will be a child (Fig. 2).

Although this study had a small sample size, the step-advanced rectangular flap could be considered an alternative choice for reconstruction of small to medium-sized soft-tissue defects overlying the Achilles region. We recommend further investigations through larger series and randomized controlled trials.

5. Conclusion

Based on our study, use of the step-advanced rectangular flap is a promising reconstruction technique for skin defects around the Achilles tendon. It is a good choice for reconstruction of small skin defects combined with Achilles tendon exposure.

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