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Achilles Lengthening and Multiple Z-Plasty in Parallel for Correction of Toe Walking Associated With Burn Scar Equinus Contracture

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ABSTRACT

The literature is sparse regarding treatment of burn scar equinus contracture, with focus primarily on staged procedures, serial casting, and gradual correction using external fixation in combination with soft-tissue procedures. This case study describes a single-stage ambulatory approach for late-stage correction of burn scar equinus contracture associated with toe walking. A case report is presented of an 11-year-old male with focus on procedure selection, surgical technique, and 12-month follow-up results. Surgery involved a single-stage approach with open Achilles lengthening, in addition to multiple skin Z-plasty in parallel with immediate protected weightbearing to correct toe walking. Inadequate release of contracture was noted intraoperatively after Achilles lengthening. Full correction was achieved after converting the longitudinal incision into multiple Z-plasty in parallel, with full heel purchase at 2 weeks postoperatively. The patient was completely healed with pain-free range of motion at 6 weeks postoperatively. At 12 months postoperatively, he continued to ambulate normally without overcorrection or recurrence of deformity. This case study describes a late-stage, minimally invasive, single-stage approach to correction of burn scar equinus contracture. The surgical principles and technique are described. Allowance of immediate weightbearing was possible because all other burn wounds were healed at late-stage presentation that avoided the need for gradual correction with external fixation or serial procedures.

Burn injuries cause damage to skin, but also can involve the underlying soft tissues, bones, and joints. Involvement of deep structures can contribute to development of contractures, especially during the early phases of healing. A prospective study by Schneider et al (1) consisting of 985 burn injuries reported that 38.7% developed at least 1 contracture by the time of discharge. Patients with longer hospital stays, higher total body surface area burns and burns that cross a joint are at greater risk of developing a contracture. Development of postburn ankle equinus contracture is not uncommon, and early therapeutic positioning and intervention is especially encouraged in the early postburn rehabilitation period when patients are often immobilized or on prolonged periods of bed rest in which the foot may be in a plantarflexed position. Treatments such as stretching, splinting, casting, orthotics, and skeletal traction have been recommended if ambulation and physical therapy is not yet possible (2). In some cases, however, postburn contractures are inevitable and surgical intervention is necessary.

Various surgical techniques to treat postburn equinus contracture have been described, including Achilles lengthening, gastrocnemius and soleus lengthening, Ilizarov fixation, and arthrodesis. Many of these are reported as multistage procedures or have the addition of skin grafts or tissue flaps because of concern for wound healing complications secondary to operating through poorly vascularized scar tissue. Soft-tissue release alone is advocated when there is no underlying bone or joint pathology; Achilles lengthening is often required for these patients. Percutaneous Achilles lengthening alone is often limited by the amount of scar tissue and fibrosis, making it less effective. Open Z-lengthening is the procedure of choice by many because it allows for sufficient correction while maintaining a low risk of recurrence (2–6). Although gradual correction using Ilizarov fixation can be considered, it requires a longer course of treatment and there is risk of recurrence once external fixation is removed. Carmichael et al (7) reported a recurrence rate of 74% in 29 pediatric ankles with postburn equinus contracture treated with Ilizarov fixation, stating that the deformity is likely to recur as the patient grows; patients may require additional procedures or arthrodesis in their lifetime. We have yet to identify any surgical treatment options in the literature that allow for immediate weightbearing postoperatively.

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Fig. 1. (*A*) Extensive scarring right leg greater than left secondary to burn injury and skin grafting. (*A*, *B*) Right heel does not purchase the ground secondary to burn-related equinus contracture.

Case Report

An 11-year-old, otherwise healthy, male was seen in consultation with the burn service in February 2017 for gait abnormality secondary to ankle equinus that developed because of prolonged immobilization and burn scar contracture. He had suffered a flame injury in 2014 resulting in 48% total body surface area burn injury. He had undergone multiple surgical debridements and reconstruction involving bilayer skin substitute and split-thickness skin graft application by the burn team over the past 3 years. He complained of toe walking and was experiencing gait-related hip, back, and neck pain. He had extensive physical therapy and was ambulatory without use of bracing or ambulatory aids.

On physical examination, he had decreased sensation to the skin graft areas, but sensation was otherwise intact. He had multiple healed skin graft scars on both lower extremities, with a large hypertrophic scar spanning his posterior right knee and extensive scarring on the right posterior calf and Achilles area. There was an abrasion to the posterior calf that appeared stable and noninfected (Fig. 1*A*). Scar tissue was adhered to the underlying muscle and tendons throughout the lower extremities, especially over the right distal Achilles. The patient was able to fully flex and extend at the knee despite scar hypertrophy. The Achilles tendon was noted to be tender on palpation, and the patient had negative 10° of ankle joint dorsiflexion with knee extension that did not improve with knee flexion. He had full muscle strength in all compartments. The right heel did not touch the ground when standing; toe walking on right lower extremity was evident on gait examination (Fig. 1*B*). His radiographs were negative other than ankle equinus on the right.

The surgical treatment plan involved open Z-lengthening of the Achilles through a longitudinal incision with conversion to skin plasty lengthening of the local soft tissues if needed to release scar contracture (Fig. 2). A longitudinal incision was made midway between traditional tendo-Achilles lengthening (TAL) and gastrocnemius lengthening incisions where the healed skin graft was flat and hopefully less adhered to the underlying tendon (Figs. 2 and 3*A*). Thick adhesions were noted between the skin graft, paratenon, and Achilles tendon, with loss of normal subcutaneous structures. The plantaris tendon was initially transected (Fig. 3*B*). A Z-shaped incision was then made into the Achilles tendon, allowing slide lengthening. The tendon was wider than the traditional TAL location because of the high incision. Complete gastrocnemius and soleus tendon lengthening was accomplished with the tendon incision down to the underlying soleus muscle belly. Muscle contracture was confirmed, which was addressed with manual stretch to tear adhesions (Fig. 3*C*). Significant lengthening was achieved, yet

Fig. 2. (*A*) Prone positioning with both feet hanging off the end of the operating room table allowed unrestricted dorsiflexion while maintaining knee extension. A folded blanket bump provided a sturdy yet padded base. Note patient's preoperative equinus contracture while under general anesthesia. (*B*) Scar tissue adhesions distally and a mid-calf wound created posterior incision challenges. Thick and blanched scar tissue at the traditional tendo-Achilles lengthening incision location with expected adhesions to the underlying Achilles tendon. The posterior wound was located at the traditional gastrocnemius recession incision location.

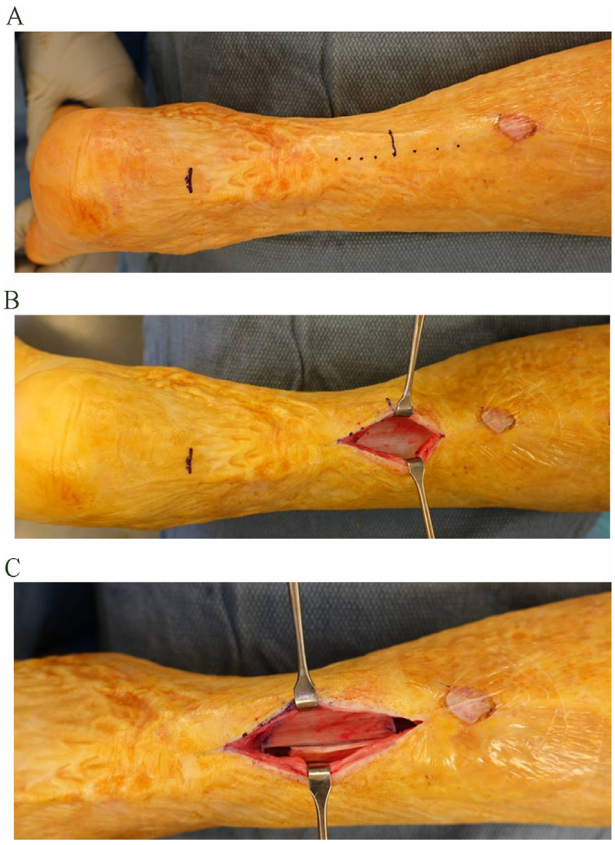

Fig. 3. (*A*) A low gastrocnemius and high tendo-Achilles lengthening incision location was used for tendon lengthening (*dotted line*). (*B*) Scar adhesions were encountered at the tendon paratenon junction, which were separated before lengthening. (*C*) Full-depth tendon incision down to the muscle allowed open Z-slide lengthening of the gastrocnemius and soleus. Deep muscle contracture was present because of longstanding deformity and prior trauma but could be stretched with forceful manipulation after tendon incision.

ankle dorsiflexion was still limited by the contracted scar tissue (Fig. 4). A decision was made to convert the longitudinal skin incision into multiple Z-plasties to allow lengthening of the overlying scar tissue. A total of 4, 60° Z-plasties were drawn along the original incision. Full-thickness skin flaps were raised, transposed, and sutured in place with 2-layer closure (Fig. 5). Final intraoperative dorsiflexion was 90° with the knee extended (Fig. 6).

Immediate weightbearing was encouraged using a fracture walker because there was minimal risk of overlengthening and a desire to

Fig. 4. Restricted ankle dorsiflexion persisted after tendon lengthening, which was due to scar contracture through the area of burn and skin graft. Note residual intraoperative equinus, which was present both with and without knee extension.

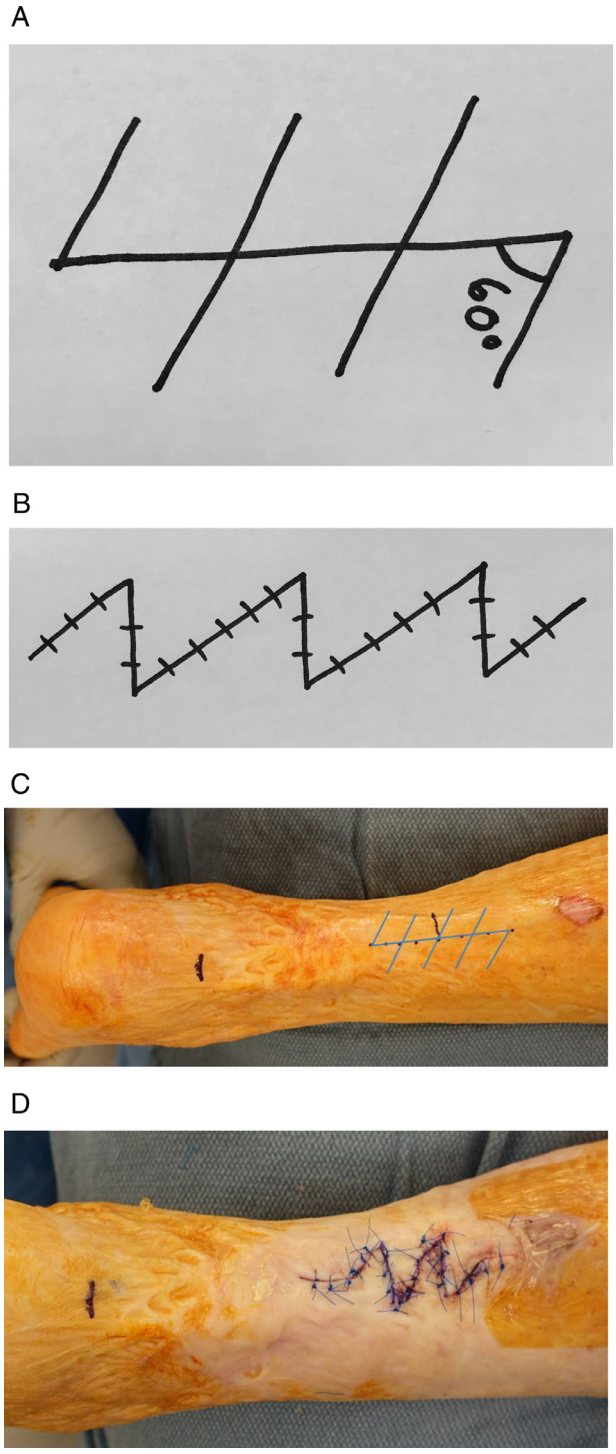

Fig. 5. (*A*, *B*) The original longitudinal incision was converted to Z-plasty in parallel using multiple 60° arms. (*C*, *D*) Transposition of flaps allowed longitudinal lengthening.

maintain stretch on the contracted tissue. The right heel was touching the ground when the patient was standing at the 2-week postoperative visit (Fig. 7). He had +5° of active dorsiflexion, and his surgical scar was healing with some open granular areas. He continued full weightbearing in the fracture boot for the next 2 weeks and then returned to regular shoes. The surgical wound was nearly healed by 6 weeks postoperatively, and he had pain-free range of motion with normal heel purchase (Fig. 8). At 12 months postoperatively, he continued to

Fig. 6. Intraoperative dorsiflexion with knee extended following tendo-Achilles lengthening and multiple Z-plasty in parallel. Note interference of operating room table, which highlights the need for optimal patient positioning with equinus surgery.

ambulate normally without pain, weakness, overcorrection, or recurrence of deformity (Fig. 9).

Discussion

The Z-plasty and various modifications have been discussed extensively in literature as a way to redirect tissue from a lax area to an area of tension or contracture. Doing so allows for lengthening along the axis of scar or contracture, thereby relieving tension at that area. The Z-plasty is designed with equal limb lengths, placing the central arm along the line of contracture. Equal lengthening in 1 axis and equal shortening in the other axis is achieved when the flaps are transposed. Proposed angles and theoretical length gained by Z-plasty include 25% gain with a 30° angle, 50% gain with a 45° angle, and 75% length gained by a 60° angle. The larger the angle, however, the more difficult it is to transpose, and the more tension is required for closure. Plus, the narrower the angle, the greater the risk of vascular compromise and flap necrosis. In practice, the actual length achieved is typically less than the theoretical length (8–10). This is based on many individual factors, such as skin elasticity, age of the patient, and anatomic location. It has been shown that there is an increase of only 40% to 60% of the proposed theoretical value. Furnas and Fischer (11) found that transposition of larger sized flaps required 7 to 10 times more tension to achieve closure; a greater amount of transposition will in turn lead to a larger dog ear. For these reasons, if >75% length is required, then additional, continuous Z-plasty is recommended, because this allows for obtaining the same amount of length as would be done with a single, large Z-plasty while avoiding too much shortening in the transverse axis. Regarding the use of Z-plasty in burn contracture, there is an increased risk of necrosis at the flap tips resulting from the required undermining and

Fig. 7. Postoperative recovery consisted of immediate weightbearing in a fracture walker to maintain stretch on the contracted tissues. Normal active ankle dorsiflexion at 2 weeks after surgery.

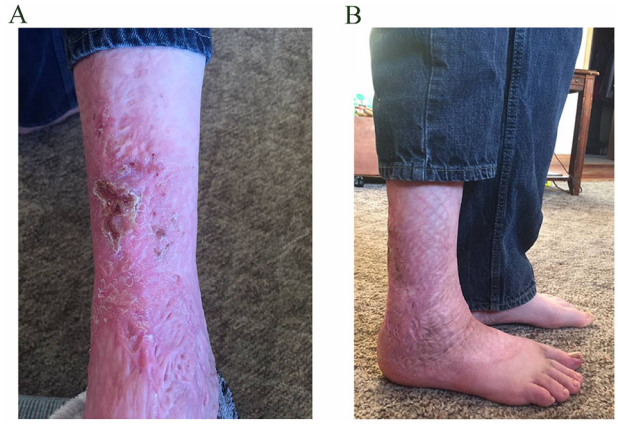

Fig. 8. (*A*) Nearly healed incision at 6 weeks postoperatively. (*B*) Patient reported normal, pain-free gait at 6 weeks postoperatively. Note normal heel purchase when standing. The patient reported no weakness despite discontinuation of the fracture boot 2 weeks prior.

transposition of scarred and fibrotic tissue. Multiple Z-plasty in parallel, as was done in this case, is a good option for long bands of contracture when the surrounding tissue may be less pliable. This requires much less of the surrounding tissue for transposition and gaining length and, overall, there is less transverse shortening and therefore less lateral tension.

When it comes to timing of soft-tissue release in burn contractures, surgery is delayed until the scar is mature. Hudson (9) noted that it may take up to 2 years for complete scar maturation and that the first 6 months after the burn will be the primary time during which contracture and scar formation occurs. Surgical intervention for contracture release while there is still active scar formation should be avoided if possible because this will lead to more contracture. Early healing is also when scar tissue is most responsive to stretching and serial splinting or casting, making early aggressive therapy important in minimizing development of postburn contracture.

In conclusion, the ideal location of tendon lengthening in this case would have been a traditional open TAL, which is performed distal to the soleus muscle that is often affected in trauma or prolonged immobilization. Hypertrophic scar tissue precluded incision in this area, which also would not have been amenable to the multiple Z-plasty in parallel approach. Percutaneous triple hemisection lengthening of the Achilles

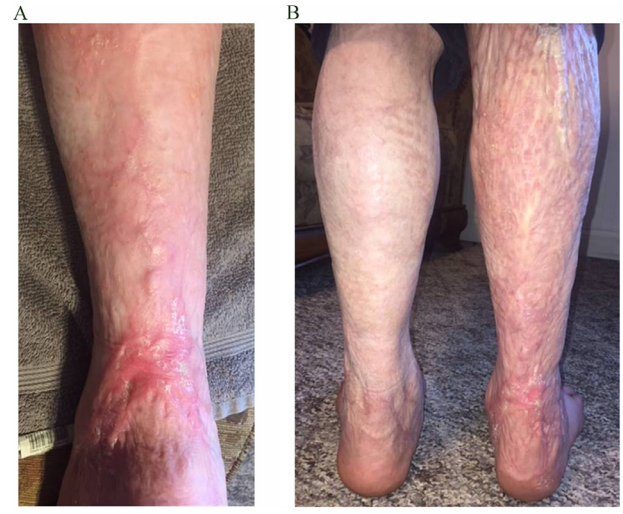

Fig. 9. (*A*) Twelve months postoperatively with barely visible healed scar. (*B*) Normal heal purchase on weightbearing without weakness, pain, or limp.

would not be as effective in this case because of expected severe scar adhesions between skin and tendon. Although there have been various articles describing treatment of postburn equinus contracture, many involve serial procedures with gradual correction using external fixation. This case demonstrates a minimally invasive soft-tissue procedure involving Achilles lengthening, skin Z-plasty, and immediate weightbearing for correction of moderate equinus in postburn contracture. Further study is needed to identify the ideal patient population and technique, which is challenging in posttraumatic conditions.

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