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

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STATEMENT OF PURPOSE

The literature is sparse regarding treatment of burn scar equinus contracture with focus primarily on staged procedures, serial casting, and gradual correction utilizing 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 which required skin plasty in addition to Tendo Achilles lengthening (TAL).

LITERATURE REVIEW

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. consisting of 985 burn injuries reported that 38.7% developed at least one contracture by the time of discharge. Patients with longer hospital stays, higher total body surface area (TBSA) burns, and burns that cross a joint are at greater risk of developing a contracture. Development of post-burn ankle equinus contracture is not uncommon and early therapeutic positioning and intervention is especially encouraged in the early post-burn rehabilitation period when patients are often immobilized or on prolonged periods of bed rest where 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]. However, in some cases post-burn contractures are inevitable and surgical intervention is necessary.

Various surgical techniques to treat post-burn equinus contracture have been described, including Achilles lengthening, gastrocnemius/soleus lengthening, Ilizarov fixation, and arthrodesis. Many of these are reported as multistage procedures or have the addition of skin grafts or tissue flaps due to 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 and 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 since it allows for sufficient correction while maintaining a low risk of recurrence [2-6]. While gradual correction utilizing Ilizarov fixation can be considered, this requires a longer course of treatment and there is risk of recurrence once external fixation is removed. Carmichael et al. reported a recurrence rate of 74% in 29 pediatric ankles with post-burn equinus contracture treated with Ilizarov fixation, stating that the deformity is likely to recur as the child grows and the patient 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 weight bearing postoperatively.

CASE STUDY

An 11 year-old otherwise healthy male was seen in consultation with the burn service for gait abnormality secondary to ankle equinus which developed due to prolonged immobilization and burn scar contracture. He had suffered a flame injury in 2014 resulting in 48% TBSA burn injury. He had undergone multiple surgical debridements and reconstruction involving Integra and STSG 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 exam, 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 non-infected **(Figure 1a)**. 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 he had negative 10 degrees of ankle joint dorsiflexion with knee extension which did not improve with knee flexion. He had full muscle strength in all compartments. The right heel did not touch the ground when standing and toe-walking on right lower extremity was evident on gait exam **(Figure 1b)**. His x-rays were negative other than ankle equinus on the right.

PROCEDURE

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 **(Figure 2)**. A longitudinal incision was made midway between traditional TAL and gastroc lengthening incisions where the healed skin graft was flat and hopefully less adhered to the underlying tendon **(Figures 2, 3a)**. Thick adhesions were noted between the skin graft, paratenon and Achilles tendon with loss of normal subcutaneous structures. The plantaris tendon was initially transected **(Figure 3b)**. A Z-shaped incision was then made into the Achilles tendon allowing slide lengthening. The tendon was wider than the traditional TAL location due to the high incision. Complete gastroc and soleus tendon lengthening was accomplished with tendon incision down to underlying soleus muscle belly. Muscle contracture was confirmed which was addressed with manual stretch to tear adhesions **(Figure 3c)**. Significant lengthening was achieved yet ankle dorsiflexion was still limited by the contracted scar tissue **(Figure 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 four, 60-degree Z-plasties were drawn along the original incision. Full thickness skin flaps were raised, transposed, and sutured in place with 2 layer closure **(Figure 5)**. Final intra-operative dorsiflexion was 90 degrees with the knee extended **(Figure 6)**.

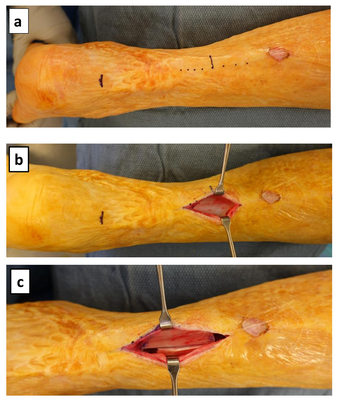
Figure 1. Preop exam of burn related equinus contracture

(a) Extensive scarring right greater than left secondary to burn injury and skin grafting. (a, b) Note how the right heel does not purchase the ground secondary to burn related equinus contracture

Figure 2. Patient positioning and incision challenges

(a) Prone positioning with both feet hanging off the end of the OR table allowed unrestricted dorsiflexion while maintaining knee extension. A folded blanket bump provided a sturdy yet padded base. Note preop equinus contracture while under general anesthesia. (b) Scar tissue adhesions distally and a mid calf wound created posterior incision challenges. Note thick and blanched scar tissue at the traditional TAL incision location with expected adhesions to the underlying Achilles tendon. The posterior wound was located at the traditional gastroc recession incision location.

Figure 3. Incision and deep exposure for TAL

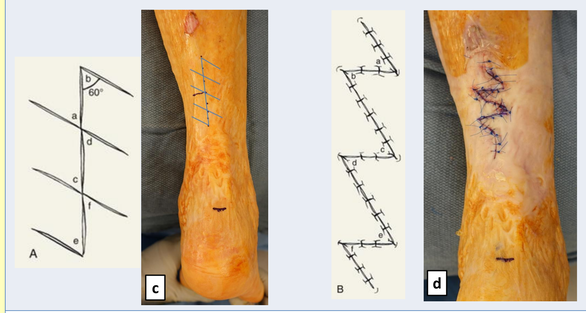


(a) A low gastroc / high TAL incision location was used for tendon lengthening indicated by the dotted line. (b) Scar adhesions were encountered at the tendon / paratenon junction which were separated prior to lengthening. (c) Full depth tendon incision down to muscle allowed open Z-slide lengthening of the gastroc and soleus. Deep muscle contracture was present due to longstanding deformity and prior trauma but could be stretched with forceful manipulation after tendon incision.

Figure 4. Residual equinus contracture after open TAL

Restricted ankle dorsiflexion persisted after tendon lengthening which was due to scar contracture through area of burn and skin graft. Note residual intra-operative equinus which was present both with and without knee extension.

Figure 5. Multiple Z-plasty in parallel to lengthen scar tissue



(a,b) The original longitudinal incision was converted to Z-plasty in parallel using multiple 60 degree arms. (c,d) Transposition of flaps allowed longitudinal lengthening.

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Figure 6. Improved dorsiflexion following Z-plasty

Intraoperative dorsiflexion with knee extended following TAL and multiple Z-plasty in parallel. Note interference of OR table which highlights the need for optimal patient positioning with equinus surgery.

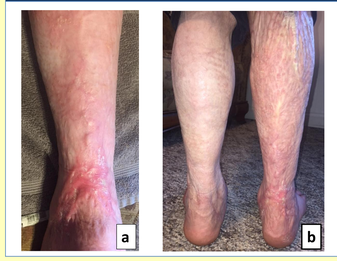
Figure 7. Active dorsiflexion at 2 weeks

Postoperative recovery consisted of immediate weight bearing in a fracture walker to maintain stretch on the contracted tissues. Normal active ankle dorsiflexion is shown here at 2 weeks after surgery.

Figure 8. Follow up at 6 weeks postop

(a) Nearly healed incision at 6 weeks postop. (b) Patient reported normal, pain-free gait at 6 weeks postop. Note normal heel purchase when standing. The patient reported no weakness despite discontinuation of the fracture boot 2 weeks prior.

Figure 9. Results at 1 year postoperative



(a) 12 months postop clinical photo with barely visible healed scar. (b) Normal heal purchase on weight bearing without weakness, pain or limp.

RESULTS

Immediate weight bearing was encouraged using a fracture walker as there was minimal risk of over lengthening and desire to maintain stretch on the contracted tissue. The right heel was touching the ground when standing at the 2 week postop visit **(Figure 7)**. He had plus 5 degrees of active dorsiflexion and his surgical scar was healing with some open granular areas. He continued full WB in the fracture boot for the next 2 weeks and then returned to regular shoes. The surgical wound was nearly healed by 6 weeks postop and he had pain-free range of motion with normal heel purchase **(Figure 8)**. At 12 months postop, he continued to ambulate normally without pain, weakness, overcorrection or recurrence of deformity **(Figure 9)**.

ANALYSIS & DISCUSSION

The Z-plasty and various modifications have been discussed extensively in literature as a way to re-direct 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 one 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 degree angle, 50% gain with a 45 degree angle, and 75% length gained by a 60 degree angle. However, the larger the angle, 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 40-60% of the proposed theoretical value. Furnas et al. found that transposition of larger sized flaps required 7-10 times more tension to achieve closure and a greater amount of transposition will in turn lead to a larger dog-ear. For these reasons, if greater than 75% length is required, then additional continuous Z-plasty is recommended, since this allows for obtaining the same amount of length as you would with a single large Z-plasty, while avoiding too much shortening in the transverse axis. Regarding the use of Z-plasty in burn contracture, one must be aware of increased risk of necrosis at the flap tips due to the required undermining and transposition of scarred and fibrosed 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 because it 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 et al. 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 as this will lead to more contracture. However, 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 post-burn contracture.

The ideal location of tendon lengthening in this case would have been a traditional open TAL which is performed distal to the soleus muscle which 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 hemi-section lengthening of the Achilles would not be as effective in this case due to expected severe scar adhesions between skin and tendon. While there have been various articles describing treatment of post-burn 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 weight bearing for correction of moderate equinus in post-burn contracture. Further study is needed to identify the ideal patient population and technique which is challenging in post-traumatic conditions.

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