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Research Article

Prophylactic Fasciotomies for Preventing Nerve Injury in Gradual Distal Tibial Deformity Correction

Edgardo Rodriguez-Collazo[1], Lee Russell Stein[2]* and Ramin Ghazizadeh[3]

[1]Department of Surgery, Presence Saint Joseph Hospital, Chicago, Illinois, USA

[2]Department of Surgery, Weiss Memorial Hospital, Chicago, Illinois, USA

[3]Weiss Memorial Hospital, Chicago, Illinois, USA

***Corresponding Author:** Lee Russell Stein, Department of Surgery, Weiss Memorial Hospital, Chicago, Illinois, USA.

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Abstract

Background: Osteotomies of the distal tibia are used to correct tibial varus deformities with the use of external fixation. One serious complication that can occur with this procedure is the development of nerve injuries. This study aimed to evaluate the effect of fasciotomies on preventing nerve injury in distal tibial deformity correction.

Methods: We reviewed two groups of patients with distal tibia varus deformities with the majority secondary to previous Pilon fractures. The first group consisted of 10 patients and the second group consisting of 17 patients. Both groups underwent distal tibial and fibular osteotomies for varus corrections utilizing gradual correction to correct angulation and translation of the malalignment. Fasciotomies were performed only on patients in the second group, which consisted of a partial opening of the anterior, lateral, superficial posterior, and deep posterior compartments of the leg before performing the osteotomy of the distal tibia. All patients were evaluated both preoperatively and postoperatively until 18 months after their external fixation removal for presence of muscle palsy, contractures, as well as, for the presence of neuritic symptoms.

Results: In the first group, where fasciotomies were not performed, neuritic symptoms were seen in all 10 patients. In the second group, there were no cases of peroneal or tibial nerve palsy or ongoing complaints of neuritic symptoms. A statistically significant difference was observed between the two groups in terms of neuritic injury ($P < 0.0001$).

Conclusion: Performing distal tibial osteotomies for distal varus deformity correction using an external fixation device to gradually correct the deformity along with the use of multiple compartment fasciotomies has shown early results that suggest nerve injury may be prevented.

Level of Evidence: Therapeutic Level 3.

Keywords: *Fasciotomy; Nerve Palsy; Angular Deformity; Tibial Osteotomy; External Fixation*

Introduction

Deformities in the distal tibia may occur due to a variety of reasons such as physeal growth arrests, tibial malunions, ankle arthritis, ankle instability, talar dome lesions, malaligned ankle arthrodesis, congenital deformities, as well as fractures [1-6]. A complication of Pilon fractures is the development of tibial varus which may be treated with distal tibial osteotomies [7-10].

Angular deformities of the distal tibia may be corrected in multiple planes. In the frontal plane, a varus or valgus deformity may be addressed. In the sagittal plane, a procurvatum or recurvatum deformity may be corrected [6]. A rotational osteotomy may be performed to correct internal or external rotation. Various types of distal tibial osteotomies have been described such as straight, dome, oblique, opening base wedge, and closing base wedge. Following the application of an external fixator, with the use of an osteotome a through and through osteotomy of both the tibia and the fibula was made through one incision. After the osteotomy was performed no acute correction was performed intraoperatively, however gradual correction was performed postoperatively. No other published study has looked specifically at the complication rate for this type of deformity correction. Additionally, this specific technique has not been described previously in the literature.

Nerve injuries as a result of lengthening procedures have been documented in the literature and ranged from 0.7% to 30% [1,11-14]. Nogueira., *et al*. [12] reported a 9.3% prevalence. The application of external fixators with trans-osseous wires can be associated with nerve injury in 10% of cases [11,15]. Axial length changes occur with various osteotomies which allow for angular correction [16].

External fixation can be used both acutely and/or gradually for deformity correction. When using internal fixation to address a deformity the surgeon lacks the ability to slowly correct residual deformity after surgery. When acutely correcting a distal tibial varus deformity with the use of bone graft and large plate fixation, there is an increased chance of causing nerve injury especially with larger deformities. Gradual correction with external fixation has the theoretic advantage of preventing injury to neurovascular structures caused by exaggerated angular reduction all at once [11]. Additionally, the tension on the neurovascular structures will be diminished, because the deformity is being corrected, and the mechanical axis is restored with the angulation and translation maneuver.

In the present study, we evaluated two groups of patients of which one series were treated without fasciotomies and in the other series the patients were treated with fasciotomies to determine whether or not nerve lesions were developed.

Materials and Methods

We retrospectively reviewed a series of 27 patients who underwent a total of 27 tibial deformity corrections, which were all performed gradually, with the use of external fixation. All patients were diagnosed with distal tibial varus either secondary to Pilon fracture or congenital tibia varum. No patients were included in either group who had a varus deformity combined with either axial plane or sagittal plane deformities. None of these patients required lengthening. Patients who had any pre-existing nerve palsy, contractures, or neuritic symptoms preoperatively were also excluded from the study. Both groups were treated from March 2012 to November 2016 by the same primary surgeon (ER). The first group was consisted of 10 patients (6 males, 4 females) who underwent a total of 10 distal tibial varus corrections. The second group consisted of 17 patients (14 males, 3 females) who underwent a total of 17 tibial varus corrections coupled with fasciotomies.

The indication for performing a distal tibial osteotomy was a varus deformity of 10 degrees or greater. The contraindications for performing this surgery were infection, poor soft tissue envelope, and severe peripheral vascular disease. The purpose of performing the fasciotomies in the various compartments of the leg in the second group was to diminish tension on the nerves running in these compartments so that they could better tolerate the angular correction.

A review of the medical charts and radiographs was performed. Data was collected over the course of four years. All patients were evaluated for the presence of contractures, peroneal or tibial palsy, as well as for sensory complaints. The patients had been followed up for 18 months after the frames were removed.

In both groups, the neurological status immediately post operatively was normal. In the first group, where fasciotomies were not performed, the mean age was 45.2 (range: 27 - 65). The mean distal tibial varus deformity was 19.8 degrees (range: 12 - 27 degrees). The mean time in the fixator was 13 weeks (Table 1). The mean age in the second group, in which fasciotomies were performed was 47 years (range: 33-66 years). The mean distal tibial varus deformity was 21.7 degrees (range: 12 - 37 degrees). The mean time in the fixator was 14.1 weeks (Table 2).

#	Age	Sex	Preoperative Tibial Varus Deformity	Palsy	Contractures	Neuritic Symptoms	Infections
1	41	Male	14	None	Flexor (digits)	Plantar	None
2	37	Male	27	None	None	Plantar	None
3	51	Male	21	None	Flexor (digits)	Dorsal	None
4	33	Female	13	Anterior Compartment*	None	Dorsal	None
5	49	Male	12	None	Flexor (digits)	Plantar	None
6	29	Male	18	None	None	Dorsal	None
7	65	Female	25	Anterior Compartment*	None	Dorsal	None
8	27	Female	23	None	None	Dorsal	None
9	63	Male	27	None	Flexor (digits)	Dorsal	None
10	57	Female	18	None	Flexor (digits)	Dorsal	None

Table 1: *Demographic characteristics of patients who received distal tibial varus corrections with the use of circular external fixation alone.*

**Transient weakness*

All patients had deformities due to Pilon fractures.

All patients were treated with Orthofix Hexapod TM frames.

The mean time in the fixator was 13 weeks.

#	Age	Sex	Preoperative Tibial Varus Deformity	Palsy	Contractures	Neuritic Symptoms	Infections
1	38	Male	18	None	None	None	Superficial Type I
2	44	Male	15	None	None	None	Superficial Type I
3	36	Female	22	None	None	None	Superficial Type I
4	52	Male	27	None	None	None	
5	63	Male	14	None	None	None	
6	45	Male	25	None	None	None	
7	65	Male	22	None	None	None	
8	33	Female	31	None	None	None	
9	34	Male	15	None	None	None	
10	56	Male	17	None	None	None	
11	51	Male	19	None	None	None	
12	45	Male	25	None	None	None	
13	43	Female	20	None	None	None	Superficial Type I
14	39	Male	25	None	None	None	
15	66	Male	12	None	None	None	
16	55	Male	25	None	None	None	
17	37	Male	37	None	None	None	

Table 2: *Demographic characteristics of patients who received tibial varus corrections.*
with the use of circular external fixation coupled with fasciotomies.
Patients #11 and #16 had congenital varus deformities. The other patients had deformities due to Pilon fractures.
Patient #5, 7, and 13 were treated with Orthofix Hexapod™ frames. The rest were treated with Orthofix TrueLok™ frames.

The mean time in the fixator was 14.1 weeks.

Surgical Technique

For the proximal leg fasciotomy, a 3 cm transverse incision was made across the proximal fibula 3 cm distal to head of the fibula overlying the lateral and anterior compartments of the leg from lateral to medial. Dissection was carried down through the superficial fascia to the level of the deep fascia. A window was then created in the deep fascia, and then the fascia overlying these compartments was then incised from lateral to medial over the length of the incision. The deep fascia was then divided 3 cm from superior to inferior in both the anterior and lateral compartments (Figure 1). Careful attention was used to help avoid damage to the common peroneal nerve or any of its branches.

Distal fasciotomy was started by a 4 cm incision was made halfway between the posteromedial border of the tibia and medial border of the Achilles tendon. Both the superficial and deep fascia of the posterior compartments of the leg were divided for 4 cm from superior to inferior, and the proximal 2 cm of the flexor retinaculum was released as well (Figure 2).

In all cases, the level of the osteotomy was determined with the use of fluoroscopy to mark the distal metaphysis (Figure 3). A 1.5 cm incision was made at that level, overlying the tibia, directly adjacent to the anterior compartment of the leg. A Hohmann retractor is used to protect the anterior soft tissue structures, as well as the neurovascular bundle. An osteotome was then used to make a straight osteotomy across the tibia taking care to preserve the periosteum at the posterior aspect of the tibia. A fibular osteotomy was created through the tibial osteotomy, with special attention to prevent injury to the peroneal artery, which lies adjacent to the fibula posteriorly. This method is beneficial because it saves time and prevents an additional surgical site. It allows for precise placement of both osteotomies at the same level, but always must be performed carefully under fluoroscopic visualization.

Application of external fixation was performed with a circular fixator, which consisted of a multiple ring system with either Orthofix TrueLok™ or Orthofix Hexapod™ frames (see tables). After the osteotomy was performed with the osteotome, the distal segment was rotated with respect to the proximal segment to complete the osteotomy. This maneuver was performed carefully to prevent over-rotation in order to reduce the risk of neurovascular injury. The distal segment was repositioned in its original place maintaining the original alignment and no acute correction of the deformity was performed, because the plan was to gradually correct for angulation and translation in the post-operative period. The struts were subsequently attached to the external fixator and locked in place (Figure 4a and 4b). Finally, imaging was used to evaluate the correction (Figure 5).

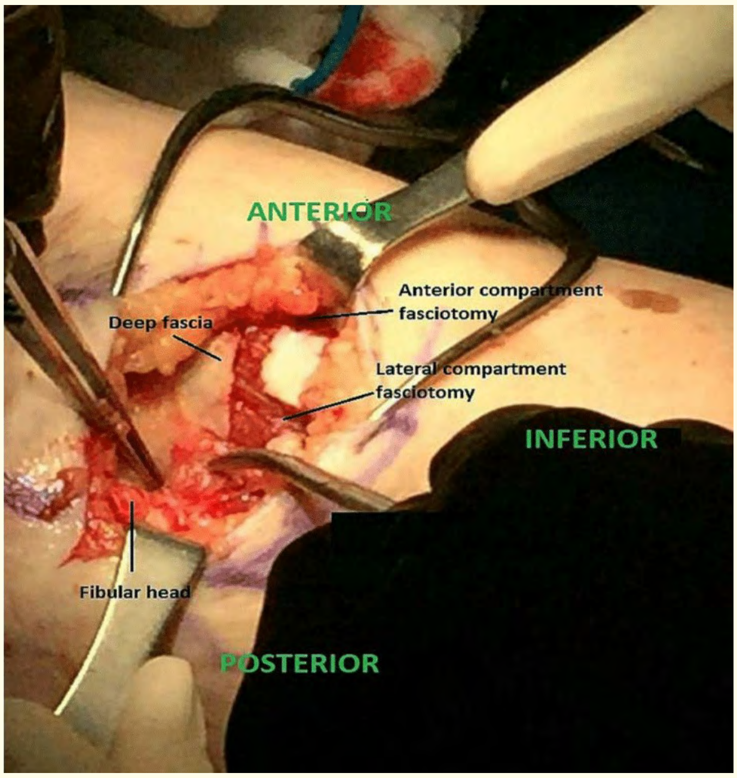

Figure 1: *Fasciotomy of the anterior and lateral compartments.*

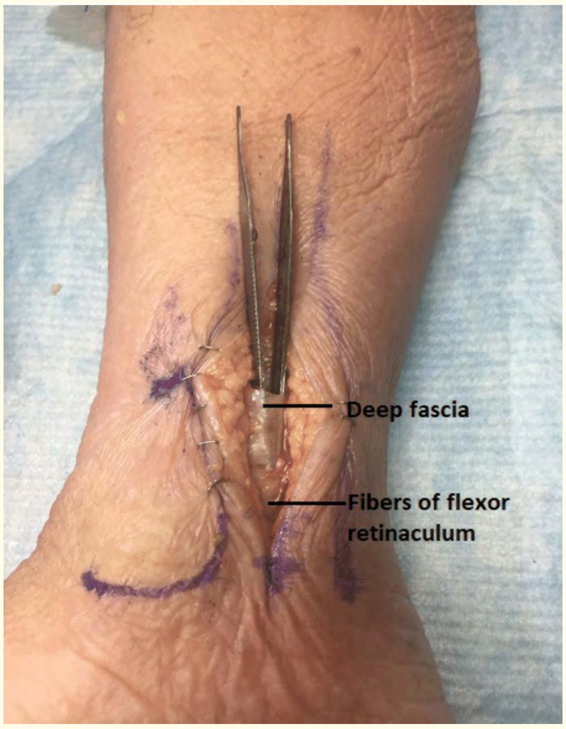

Figure 2: *Performing flexor retinaculum release (shown on cadaveric limb).*

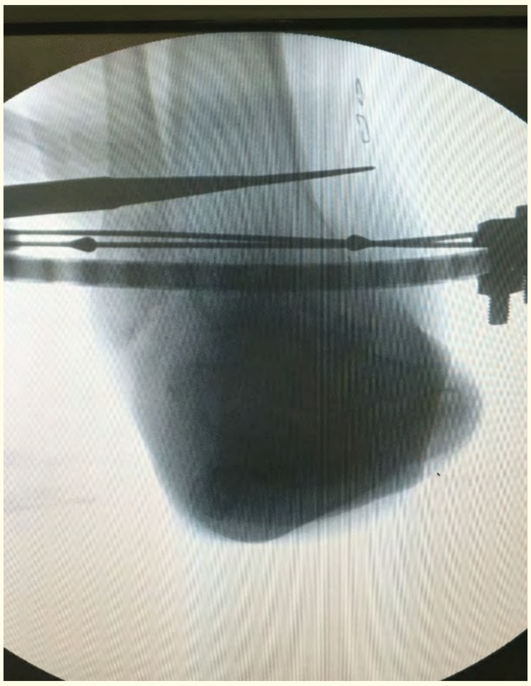

Figure 3: *The level of the osteotomy is marked under fluoroscopy.*

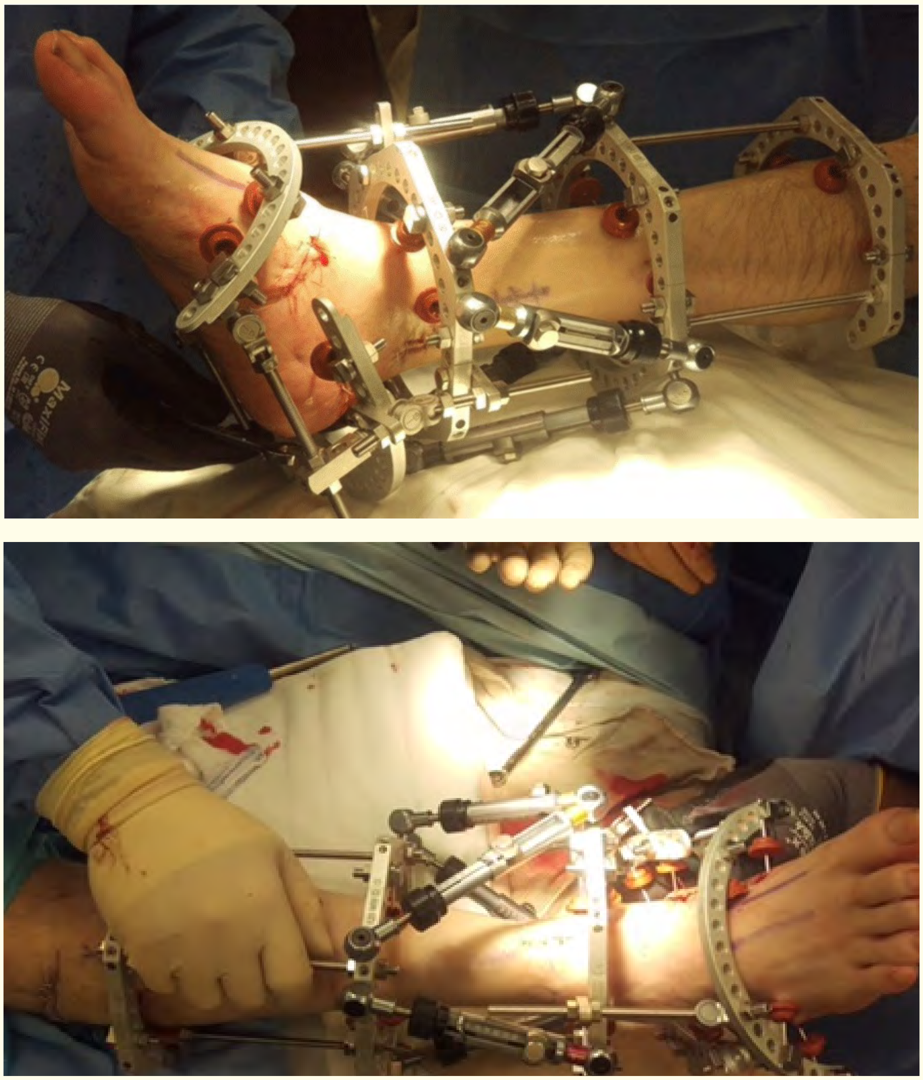

Figure 4: *Multiple ring fixator construct (Fig. 4 a and b).*

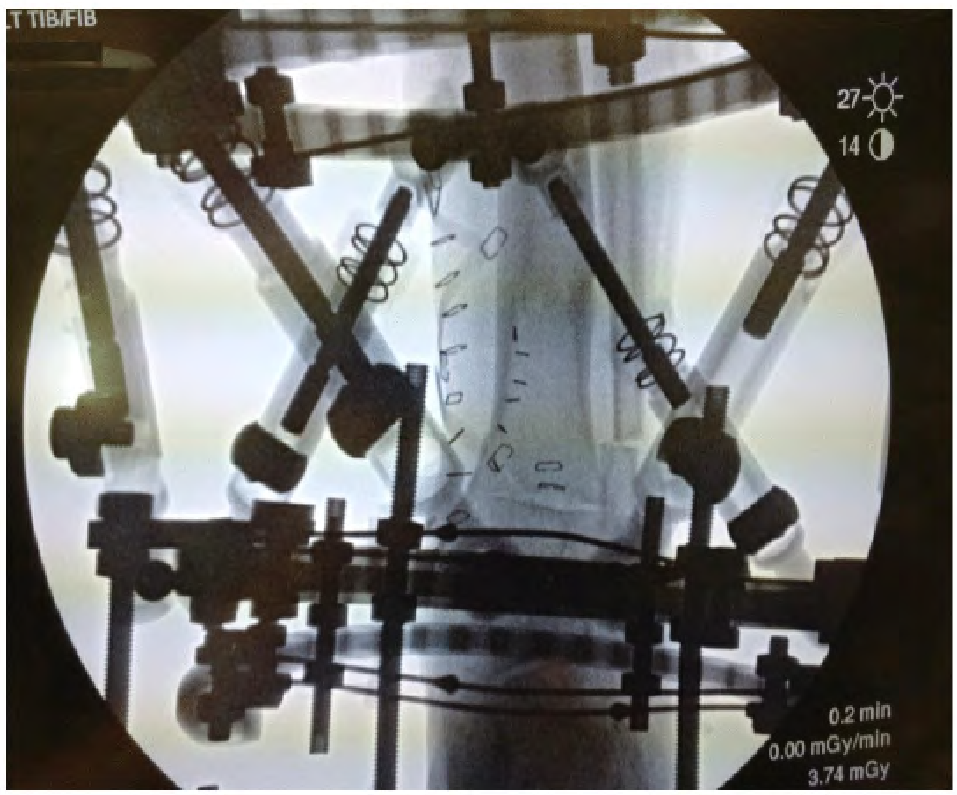

Figure 5: *Fluoroscopy image after osteotomies*

Postoperative Care

Patients were allowed to bear weight as tolerated with a gait assistive device. Also, the same rate of 0.5 mm per day of distraction for gradual correction was utilized on all patients following a latency period of 12 days to allow the soft tissue inflammation to subside. In the first group, the period of gradual correction was an average of 40 days, with average consolidation period being 79 days, and a mean time of 13 weeks in the fixator. In the second group, the period of gradual correction was an average of 43 days, with an average consolidation period of 87 days, and a mean time of 14.1 weeks in the fixator. In all patients the frame was removed after radiographic signs of healing were confirmed by CT scan. At this time, patients were treated with a fiberglass partial weightbearing cast as tolerated for 4 weeks, and then with a patellar tendon bracing, which was used for a period of 6 months.

Statistical Analysis

Statistical analysis of data was performed using the SPSS software (SPSS Inc., Chicago, IL). Data were recorded as mean ± SD. Categorical variables between the study groups were compared using the Chi-square test or extension to Fisher exact test. A P value of < 0.05 was considered significant.

Results

In both groups, the neurological status immediately post operatively was normal. In the first group, with no fasciotomies performed, neuritic symptoms were reported on the plantar aspect of the foot in three patients and on the dorsal aspect of the foot in seven patients. These sensory symptoms appeared during the gradual correction phase, however all patients' symptoms had resolved by the final post-operative visit at 18 months after frame removal. Symptoms were managed by reducing the rate of distraction as well as with GABA analogues.

Two patients in the first group developed brief weakness of dorsiflexion of the ankle and toes after frame removal, which was assessed via manual muscle testing. No findings consistent with hematoma or excessive edema in any compartment were seen postoperatively to suggest compartment syndrome. Both of these patients regained full muscle strength by the final visit, at 18 months after removal of the frame. No complications were severe enough to warrant postoperative fasciotomies, nerve decompressions, or nerve repair. However, five patients in this first group developed contracted digits which were subsequently successfully treated surgically with flexor tenotomies at the plantar aspect of the digits. No cases of peroneal or tibial nerve palsy or complaints of neuritic symptoms in the lower extremities were reported in patients in the second group who underwent multiple fasciotomies of the leg throughout the correction period and up until 18 months after removal of the frame. Four patients developed superficial type 1 infections in this group all of which were managed with either oral antibiotics or local pin site care. No vascular changes were seen in either group. A statistically significant difference was observed between the two groups in terms of neuritic injury ($P < 0.0001$, Chi-square test; $P < 0.0000$, Fisher exact test).

Discussion

Wagner stated that nerve injury is caused by compression from fascial tension during limb lengthening. Decompression of the nerve by fasciotomy was his suggestion [17]. Nerve decompression has been advocated with deformity correction and lengthening cases [14-17,27]. Distal tibial osteotomies and deformity corrections can stretch the posterior tibial nerve whether a varus to valgus, a procurvatum to recurvatum, a derotational, or an equinus correction is performed [5,7,16].

Decompression of the peroneal nerve is a common technique for the treatment of peroneal nerve palsy and entrapment [27-29]. Paley performed common peroneal nerve decompression at the level of the neck of the fibula at the entrance of the of the peroneal muscle fascia for various lengthening and deformity correction procedures of the tibia. He recommended releasing the intermuscular septum between the lateral and anterior compartments, as well as longitudinal releases down each compartment [16]. Its efficacy has been determined biomechanically to relieve rigidity of compressed nerves during deformity correction in cadaveric specimens [27].

In our study, no decompression of the common peroneal nerve was performed at the level of the neck of the fibula, however, it was found that acute varus deformity corrections of more than 10 degrees would benefit from a prophylactic fasciotomy of the superficial, lateral, and deep compartments of the leg. The purpose for incorporating this proximal fasciotomy in the second group of patients was that in the first groups, signs and symptoms were likely associated with nerve injury in the anterior compartment.

Paley also has advocated performing a fasciotomy of the deep posterior compartment of the leg, release of the tarsal tunnel, as well as releasing the fascia above and below the abductor hallucis to prevent nerve palsy. In the second group of patients, the distal fasciotomy was performed at the level superior to the tarsal tunnel and included the proximal 2 cm of the tarsal tunnel. A full tarsal tunnel release with associated nerve branches [19] was not performed in the group of patients who underwent fasciotomies, because no pre-existing nerve pathology was identified on any of these patients, and because the procedure was performed as a prophylactic maneuver. The deep fascia of the posterior compartment is contiguous with the tarsal tunnel and in some cases, there may be a high bifurcation of the tibial nerve. Our preference is to stay away from the various branching of the tibial nerve to avoid complications. Additionally, there is a greater occurrence of poor wound healing as the incision is brought more distally into the tarsal tunnel. It is more likely to encounter more bleeding with a decompression of the tarsal tunnel and the branches of the tibial nerve and vessels which can cause wound dehiscence.

When a nerve injury occurs, postoperatively the patient may have symptoms including pain, hyperesthesia, hypoesthesia, muscle weakness, and possible paralysis [18]. Possible causes for nerve palsy and paresthesia associated with lengthening procedures are wire interference, compartment syndrome, traction [1], or damage from the twisting motion from completing the cortical fracture [14]. The patient may develop a foot drop or tibial nerve dysfunction [20]. If lengthening is continued after a nerve injury occurs, a permanent nerve lesion may develop [12,18,21,22], in some instances a full recovery of the nerve may occur when a nerve release is performed such

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The pathophysiology of traction on nerves is been better understood in animal models. According to the literature, nerves can undergo an increase in length of 4-11% before structural compromise occurs from a histological standpoint [23-25]. Further stretching of a nerve beyond 8% results in a decreased perfusion by narrowing of the intraneural and extra neural microcirculation. This in turn can lead to a reversible loss in nerve function. Experimentally, elongation of approximately 15% can cause complete occlusion of blood vessels which will result in total ischemia to the nerve [24,25]. When neural ischemia occurs perineural scar tissue forms which may interfere with blood flow as well as axonal sprouting [25,26]. These changes can be expected to result in significant disturbances in nerve function.

In our study, all patients who had history of Pilon fractures had intra-articular deformities in the coronal plane, and these were corrected with extra-articular osteotomies. The results of present study are notable in that none of the 17 legs that underwent a distal tibial osteotomy with external fixation and adjunctive fasciotomies developed any foot drop, intrinsic muscle palsy, contractures, or sensory disturbances.

In comparison, in the series of 10 patients who underwent the same deformity correction procedure without fasciotomies, all patients had findings consistent with nerve injury. Although this is a high number of complications in the group without fasciotomies, the severity of complaints was such that 5 of the 10 patients required flexor tenotomies for digital contractures and no one with sensory complaints required any nerve surgery or decompressions.

The fasciotomy technique became incorporated into the second group of deformity cases in this study as standard protocol because multiple patients had sustained some type of nerve-related injury during the time the first group of patients were treated. It is plausible that some of the nerve injuries seen in the first group may have occurred due to wire or half pin placement. We advocate the use of safe zones for the placement of wires and half pins, which have been described in order to protect neurovascular structures of the lower limb [30-35].

After the fasciotomy technique was performed on the patients in the second group, no nerve injuries or neuritic symptoms were observed. Awareness of clinical findings of nerve lesions postoperatively is paramount. This will enable the surgeon to take full advantage of the ability to adjust the external fixation device to obtain maximum deformity correction at a rate and range that will attempt to minimize nerve damage.

Conclusion

The short-term results of prophylactic fasciotomies for preventing nerve injury in gradual distal tibial deformity correction are encouraging. The evidence advocates the performance of adjunctive prophylactic fasciotomies in all distal tibial varus correction cases. Nevertheless, further retrospective and prospective studies of a long-term nature on larger patient population are needed to confirm the efficacy of this approach.

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Conflicts of Interest

There are no conflicts of interest.

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