A bloodless technique for correction of equinovarus deformities by Taylor spatial frame: a prospective case series

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ABSTRACT
Background: Rigid ankle and foot deformities as a sequela of relapsed talipes equinovarus or vascular or neurological disorders are a challenge for orthopedic surgeons. This study introduces a bloodless technique to correct the deformities of the ankle in patients with these disorders using the Taylor Spatial Frame (TSF).

Methods: Eighteen feet in 18 patients with equinovarus deformities were prospectively enrolled in this study. All patients underwent preoperative clinical evaluation that included neurovascular assessment. Deformity components were measured using a goniometer. All patients had gradual correction of the rigid equinovarus ankle and foot by TSF without any soft-tissue or bony procedures. Preoperative and postoperative ankle and foot equinus and varus angles, in association with the American Orthopaedic Foot and Ankle Society (AOFAS) score, were used for assessment of the functional outcome.

Results: There were 13 male patients (72.2%) and five female patients (27%). The mean age of the patients was 25.89 (range 14 to 43, SD 7.28) years. The right side was affected in 11 patients (61.1%), and left side was affected in seven patients (38.9%). At the final follow-up the average AOFAS ankle hindfoot scores improved from 25.17 (range 12 to 39, SD 9.91) preoperatively to 74.78 (range 48 to 88, SD 15.33) postoperatively, (t = 22.13, P < 0.001). Fifteen patients (83.3%) were categorized as "good", and three patients (16.7%) were categorized as "fair".

Conclusions: TSF is a safe, effective, and simple method of correcting rigid equinovarus deformities of the ankle without soft-tissue releases or bone osteotomies and is a bloodless technique.

Level of Evidence: Level IV.

INTRODUCTION
Rigid equinovarus deformity often is seen in patients who have congenital clubfoot and have been neglected or have relapsed as a sequela of ischemic contracture of the leg or peripheral nerve injuries, and it is rarely due to myelodysplasia or poliomyelitis. It represents a challenge to orthopaedic surgeons because classic open procedures, including soft-tissue releases and osteotomies usually yield bad results with high recurrence and complication rates. Such risks increase with revision surgeries or in patients with soft-tissue scarring from previous surgeries, which makes correction with an external fixator the most suitable option.

The Taylor Spatial Frame (TSF) (Smith and Nephew, Memphis, Tennessee, USA) is a circular external fixator consisting primarily of two rings or partial rings of variable sizes connected by six telescoping struts with universal hinges that creates a hexagonal frame and is adjusted by a software application. It is a successful alternative to the Ilizarov external fixator in acute trauma, nonunion, and deformity corrections. The TSF allows for much greater precision in deformity correction when compared to the Ilizarov.

Foot and ankle deformities represent a good example of complex deformities where multiplane correction is needed. The Ilizarov fixator has been successful for management of such deformities. However, there are very few studies presenting management of ankle and foot deformities using TSF, especially in adults. This study included patients in a variety of age groups. The purpose of this study was to review the results of managing equinovarus deformity using the bloodless technique of a TSF without performing soft-tissue releases or corrective osteotomies. The hypothesis was that TSF would be effective in treatment of equinovarus deformities of foot and ankle without need for osteotomies or soft-tissue releases.
MATERIALS AND METHODS

Ethical Review and Study Design
After institutional review board approval (IRB# Ortho.Surg. 15-2013) 18 feet in 18 patients with equinovarus deformities were prospectively enrolled between May 2013 and August 2017. All patients provided written informed consent.

Patient Selection
All patients underwent preoperative clinical evaluation that included neurovascular assessment. Deformity components were measured clinically using a goniometer and plain anteroposterior and lateral radiographs of the weight-bearing ankle and foot to measure equinus and varus angles. Ankle and foot CT with three-dimensional reconstruction to evaluate the condition of the ankle and the subtalar joints were also obtained. Inclusion criteria included stiff uncorrectable equinovarus deformity with severe contracture, bad skin condition, or multiple previous surgical procedures. There were no exclusion criteria for this study.

Data Collection
All patients underwent gradual correction of the rigid equinovarus ankle and foot by TSF without any soft-tissue or bony procedures. Preoperative and postoperative equinus and varus angles of the ankle and foot in association with the AOFAS score,5,6 were used for assessment of the functional outcome. The scores are good (complete correction and no pain), fair (partial correction with plantigrade foot and occasional pain), or poor (nonplantigrade foot and continuous pain during walking).

Surgical Technique
Under complete antiseptic conditions, both general and spinal anesthesia were used, and both old (complete ring) and new (separate half ring) versions of the apparatus were used in this study.

The proximal ring of the old version of suitable size was inserted first around the leg without any fixation, then the distal ring was assembled in equinovarus position at the same angle of the deformed ankle. The full ring was used around the foot because the foot frame was not available. The distal angle of the deformed ankle. The full ring was used around distal ring was assembled in equinovarus position at the same fixation, then the apparatus, patients were admitted to our hospital during the whole period of deformity correction. The correction was observed daily until the end of the correction sheet. Residual deformity was tabulated again, and a new prescription sheet was obtained until the foot and ankle became plantigrade (Figure 2). Removal of the fixator was performed under general anesthesia, and a short walking cast was applied for 1 month.

Statistical Analyses
A sample size calculation was not performed in this study because all patients who had stiff equinovarus at our facility during the time of this study were included. Software (SPSS, Version 20.0 for Windows, SPSS Inc, Chicago, IL) was used for the univariate, bivariate, and stratified analyses of the data. Paired test and Wilcoxon test were applied for the comparison of quantitative variables after establishing their normal distribution by one-sample Kolmogorov-Smirnov test of normality. Differences were considered significant at P ≤ 0.05.

RESULTS
Patients demographic data are outlined in Table 1. There were 13 male patients (72.2%) and five female patients (27%), the mean age of the patients was 25.89 (range 14 to 43, SD 7.28) years. The right side was affected in 11 patients (61.1%), and the left side was affected in seven patients (38.9%). The etiology of the ankle and foot deformity was recurrent deformity of talipes equinovarus after multiple surgical procedures in 12 patients (66.7%) and posttraumatic Volkmann ischemic contracture in six patients (33.3%).

The mean operative time needed for apparatus application was 65.6 (range 45 to 90) minutes. The mean time needed for full correction of the deformity was 23.83 (range 16 to 36, SD 5.33) days. The mean time of fixator application was 136.44 (range 120 to 160, SD 11.72) days. The average follow-up period was 25 (range 15 to 40) months after removal of the cast.
The mean preoperative varus ankle angle was 55.89 degrees (range 35 to 75, SD 12.91) degrees, and the mean postoperative varus ankle angle was 1.44 (range 0 to 8, SD 2.25) degrees ($z = 3.73, P < 0.001$). The mean preoperative equinus ankle angle was 61.17 (range 30 to 81, SD 13.43) degrees, and the mean postoperative equinus ankle angle...
was 0.83 (range 0 to 5, SD 1.58) degrees (z = 3.75, P < 0.001) (Table 2).

At the final follow-up the average AOFAS ankle hindfoot scores improved from 25.17 (range 12 to 39, SD 9.91) preoperatively to 74.78 (range 48 to 88, SD 15.33) postoperatively (t-test = -22.13, P < 0.001). Fifteen patients (83.3%) were scored as good and three patients (16.7%) as fair.

Two patients were reported to have pin track infections that were superficial and treated with dressing and antibiotics. Only one patient with Volkmann ischemic contracture developed recurrent varus deformity of 10 degrees, and the patient was satisfied and refused further intervention. No neurovascular complications were reported during or after the correction.

**DISCUSSION**

Since Ilizarov popularized the principle of tensile stress, many complex orthopedic deformities have been addressed. Applying gradual traction to bone and soft tissues using his circular apparatus leads to deformity correction by the stimulation of metabolic activity and regeneration power in both bone and soft tissue. The Illizarov external fixator is preferred in multiplane deformities when both rotation and translation are needed. However, the need for constructing configuration adjustment, and the long learning curve for rotational corrections are the main limitations of the Ilizarov apparatus that were solved by the development of TSF.

In the current study, we present the technique and results of applying the same principles as Ilizarov with the use of TSFs in gradual correction of complex equinovarus deformities without osteotomies or soft-tissue releases, which is a bloodless technique. Full correction could be achieved in an average of 23.83 (range 16 to 36) days, with only minor recurrence in one patient and without remarkable complications.

Many authors believe that osteotomies and or soft-tissue releases must be done at the time of deformity corrections with Ilizarov in patients who are older than 10 yr. However, others obtained correction of the deformities without osteotomies or soft-tissue releases in pediatric and adult patients. Soft-tissue releases are hazardous for patients who have thin skin or soft-tissue scarring, and osteotomies usually accompany removal of large bone wedges to achieve correction, which results in shortened feet.
Cuttica et al.\textsuperscript{8} used the TSF and similar multiplanar external fixation devices after extensive posteromedial soft-tissue releases for gradual correction of rigid equinovarus deformities in eight patients. They achieved correction in seven patients with an average duration of external fixation of 10.8 weeks (range 8 to 16 ± 2.8) weeks. The time needed for deformity correction in that study was 4 to 6 wk. In our study, full correction was obtained in 2 to 5 wk, and the total time of fixator application was 17 to 23 wk.

Cuttica et al.\textsuperscript{8} reported high complication rates in about half of their patients, including vascular injury, infection, and recurrence of deformity. Moreover, the open technique was unsuitable for patients with contracted scarred soft-tissue from multiple previous operations. In our series using a bloodless technique, we achieved correction in all patients with no osteotomies or soft-tissue releases and avoided such complications. Table 3 compares the results of our study to other studies\textsuperscript{9,10} that combined TSF with other procedures and resulted in higher complication rates.

The reported operative time of Ilizarov application ranges from 2.5 hr\textsuperscript{6} to 8 hr\textsuperscript{11,12} Assembly of the apparatus before surgery was found to shorten operative time.\textsuperscript{13} Our average operative time was 65.6 (range 45 to 90) minutes, reflecting the simplicity of this procedure when compared to use of the Ilizarov frame.

Wukich et al.\textsuperscript{14} described several types of frame configurations for correction of foot and ankle deformities, and they concluded that TSF should be reserved for severe deformities. In this study, we present a simple frame of two rings with different levels of wire fixation. The key technique in our approach is changing the center of correction rather than usage of multiple rings.

Mangagla et al.\textsuperscript{15} compared the outcome of deformity correction of the foot and ankle using TSF versus Ilizarov. They concluded that TSF has a better outcome than the Ilizarov. Several authors described foot and ankle osteotomies in association with TSF application,\textsuperscript{8,10,14,15} and others described soft-tissue release and tendon lengthening.\textsuperscript{16} Regarding the other types of computer-assisted deformity correction devices, Takata et al.\textsuperscript{17} described several constructs for correction of foot and ankle deformities using the Ortho-SUV frame (OSF; Ortho-SUV Ltd, St. Petersburg, Russia). Riganti et al.\textsuperscript{18} reviewed 10 patients with foot and ankle deformities who were treated with the Ortho-SUV frame and supramalleolar and V-shape foot osteotomy. They reported...
### Table 3. Comparison of current study to different studies using Taylor Spatial Frame (TSF) in complex foot deformities

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Etiology</th>
<th>Surgical technique</th>
<th>Results</th>
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<td>Eidelman et al.⁹</td>
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| - Fifteen patients.  
- Mean age was 6.5 yr.  
- Mean time of frame was 3.6 mo. | - Idiopathic talipes equinovarus.  
- Developmental club foot.  
- Fibular hemimelia club foot. | Two types of frames were described:  
- Ponsetti-Taylor type 1  
  Stage A:  
  - Two rings, proximal in tibia, distal at the ankle and foot.  
  - Wire was inserted in the distal tibial physeal plate connected to the proximal ring.  
  - Olive wire inserted into the talus attached to the proximal ring to prevent talar rotation during varus correction.  
  Stage B:  
  - Remove the talar wire from the proximal ring and reattach to the distal ring.  
  - Tibiotalar distraction, over correction of equinus by 20 degrees.  
- Ponsetti-Taylor type 2  
  - Same as type 1 but with correction of foot cavus and adductus. | - One patient had talar subluxation.  
- One patient had metatarsophalangeal joint subluxation.  
- One had residual equinus and forefoot adductus.  
- Two patients undercorrected.  
- Nine patients had superficial pin track infection.  
- One patient had revision. |
| Waizy et al.¹⁰ | | | |
| - Seven patients, Eight severe foot and ankle deformity.  
- Mean age of the patients was 15.1 yr. | - Residual deformity talipes equinovarus with multiple surgical procedures. | | |
| Current study | | | |
| - Eighteen patients, 13 males and 5 female.  
- Mean age was 25.89 yr. | - Six patients had post traumatic Volkman ischemic contracture.  
- Twelve patients had sequela of residual club foot deformity, one patient had fibular hemimelia with talipes equinovarus. | One frame technique:  
First stage:  
- Complete ring on the ankle and foot take the shape of the deformity in the foot and ankle.  
- Complete ring on the tibia.  
- Olive wire inserted in the talus attached to the distal ring until the position of the talus is corrected inside the ankle mortis.  
- Wire in the metatarsal bone attached to the distal ring.  
Second stage:  
- Release the tension in the talar wire but still attached to the distal ring to keep the position of the talus. | - According to Fierreira criteria, seven patients were good, fair in one patient, poor in none.  
- No foot was corrected to full physiological position.  
- Five feet had pathological supination in the forefoot.  
- Correction was achieved in all patients without over correction in any deformity plane.  
- One patient had recurrence of mild varus ankle deformity. |
eight feet plantigrade and relapses in two patients. The results had AOFOS scores that were classified as good in six, fair in two, and poor in two, which improved from 33.9 preoperatively to 67.25 postoperatively. In our study, the average AOFAS improved from 25.17 (range 12 to 39) preoperatively to 74.78 (range 48 to 88) postoperatively. Fifteen patients (83.3%) were scored as good, and three patients (16.7%) were fair.

Several observations were noted in this study. The correction steps were easier in young patients than adults, and pain tolerance was good in all age groups. Great care was taken in correction steps in skeletally immature patients to avoid physeal injury. Pin-track infections and soft-tissue complications were not affected by the etiology of the deformity or the age of the patients because the correction was done gradually. During the follow-up period, younger patients reported greater satisfaction than adults.

Limitations and Future Perspectives

The main limitation of this study is the lack of direct comparison to the other modalities of treatment of equinovarus foot and ankle deformity. However, published studies about the use of TSF in the management of foot and ankle deformities, especially in adults, are limited and have small sample sizes with little description of surgical techniques. Future comparative study is planned to compare TSF and Ilizarov fixators in the management of rigid equinovarus feet.

CONCLUSIONS

In the current study, we presented a bloodless technique with the use of a simple construct of TSF with changeable reference centers in the management of severe equinovarus deformities associated with a soft-tissue compromise. We concluded that TSF is a safe and simple bloodless technique for correcting rigid equinovarus deformities without soft-tissue releases or bone osteotomies and has a satisfactory clinical outcome.

REFERENCES


