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ORIGINAL STUDY

Management of adolescent tibia vara using Taylor spatial frame

Mohammed Anter Meselhy

Benha Faculty of Medicine, Orthopedic Surgery, Egypt

***Purpose* : Adolescent tibia vara is a multiplanar deformity that can lead to progressive deformity, altered gait, unequal leg lengths, and premature knee arthritis if uncorrected. The purpose of the current study is to report our experience in management of adolescent tibia vara using Taylor Spatial Frame (TSF).**

***Materials and Methods* : A prospective study of eleven adolescent tibia vara patients managed by proximal tibial osteotomy gradual deformity correction using TSF.**

***Results* : The average time in the frame was 123.5 (±25.5) days. At final follow up (average 15 (±2) months), the mean post-operative mPTA was 87 (±4) degrees (range 81 to 93 degrees), where the mean preoperative mean mPTA was 68 (±9) degrees (range 49 to 77 degrees) (p value 0.003).**

The mean postoperative MAD was 12.2(±11.4) mm, range (-1 to 26 mm), where preoperative mean MAD was 75.7(±14.7 mm), range (60 to 107mm) (p value 0.003).

The mean postoperative PPTA was 80(±2) degrees, range (77 to 83 degrees), while the preoperative mean PPTA was 72 (±12) degrees, range (42 to 82 degrees) (p value 0.028).

***Conclusion* : Although we have not directly compared the TSF with the Ilizarov fixator, this series serves to highlight the versatility and effectiveness of the TSF in the treatment of complex and often obstinate adolescent tibia vara.**

INTRODUCTION

Adolescent tibia vara is a multiplanar deformity that can lead to progressive deformity, altered gait, unequal leg lengths, and premature knee arthritis if uncorrected *(9)*.

Multiple treatment options exist, depending on the nature and severity of the deformity and include bracing or casting, or either acute or gradual surgical correction. Surgical treatment can be accomplished using a variety of devices such as, kirschner wires, monolateral and circular external fixators and intramedullary devices *(8,9)*.

Osteotomy for infantile and adolescent tibia vara is indicated to correct the deformity, equalize limb lengths, and ameliorate symptoms. Acute corrective osteotomy has been complicated by peroneal nerve palsy, compartment syndrome, residual deformity, limb length inequality, delayed union, and failure of fixation *(4)*.

The use of an external fixator offers many advantages in the correction of pediatric lower extremity deformities, including the ability to correct multiplanar deformities simultaneously, avoiding risks

■ Mohammed Anter Meselhy
Benha Faculty of Medicine, Orthopedic Surgery, Egypt
Correspondence : Mohammed Anter Meselhy, Benha Faculty of Medicine, Orthopedic Surgery, Egypt
E-mail : m.anteroof@yahoo.com

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of acute correction on nerves and blood vessels, adjusting the correction during the treatment process without revision surgery, and the avoidance of postoperative cast immobilization while maintaining joint range of motion and often allowing weight bearing *(4,9)*.

For applying Taylor spatial frame (TSF), the deformity must be described in terms of the six axes or degrees of freedom. These axes include angulation and translation in each of the coronal, sagittal, and axial planes. The appropriate-sized ring, known as the reference ring, must be chosen and mounted correctly to the affected extremity *(1,7)*.

Deformity parameters including angulation, translation and rotation, as well as, the relationship between this ring and the deformity, known as the mounting parameters, are then entered into the computer program. The mounting parameters determine the relationship of the deformity to the reference ring. The position of the other ring is calculated by the computer using the ring sizes and strut lengths. From this point, the desired correction can be entered into a computer program that determines the sequence of strut length adjustment *(1,7)*.

In contrast to Ilizarov devices, which require precise mounting of hinges to achieve deformity correction, the TSF creates a ‘‘virtual hinge’’ using the six struts, making it technically much easier to apply. In addition, a residual deformity correction can be performed at any time during the correction, essentially creating a new virtual hinge, without the need to return to the operating room for frame or hinge adjustment *(1,7,8)*.

Table I. — The age, gender and duration of fixation by T.S.F.

	Value
Age	
Mean ±SD, Range	15.73±2.02,(13-19) years
Sex	
Male	7 (63.6 %)
Female	4 (36.4 %)
Duration of fixation	
Mean ±SD, Range	123.45±25.45, (85-166) days

MATERIAL AND METHODS

Between March 2010 and April 2014, eleven patients with adolescent tibia vara were prospectively included in the current study. The study protocol was approved by Benha University ethical committee review board.

There were seven males (63.6%), and four female (36.4%) with mean age of 15.7±2 years at operation (Table I). Eight cases were right and three were left. The aetiology of tibia vara was adolescent Blount disease in 8 cases, bone softening disease in 1 case (osteomalacia), and traumatic tibia vara in 2 cases. The main complain of all patients is bow legs, pain and inability to walk and falling down in running. Three had lateral knee thrust during walking.

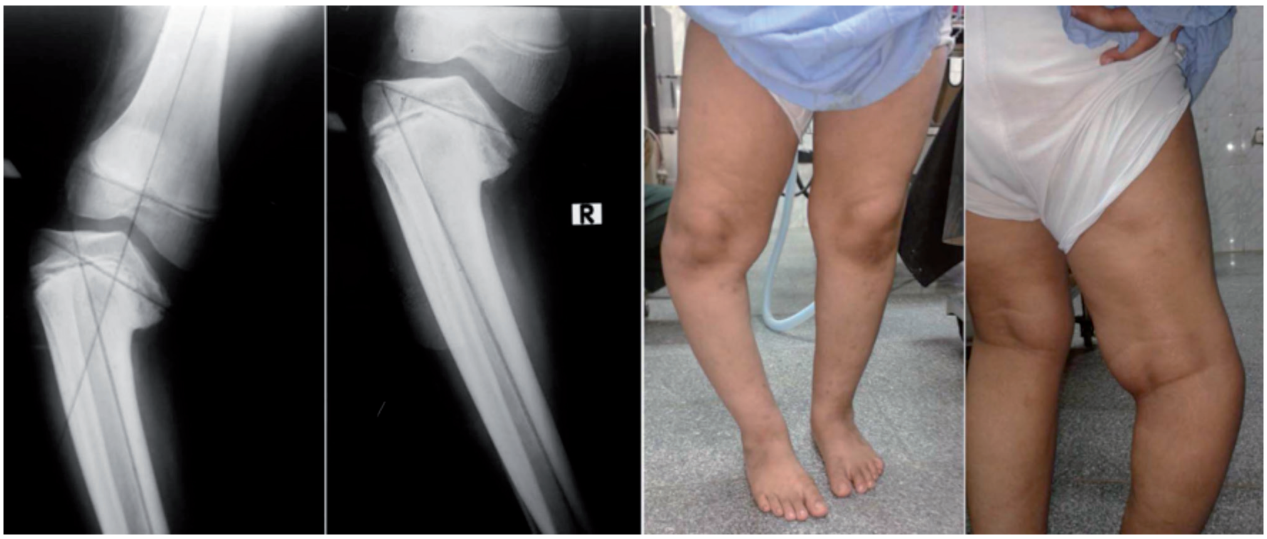

Fig. 1-A. — Pre operative X rays and clinical photos.

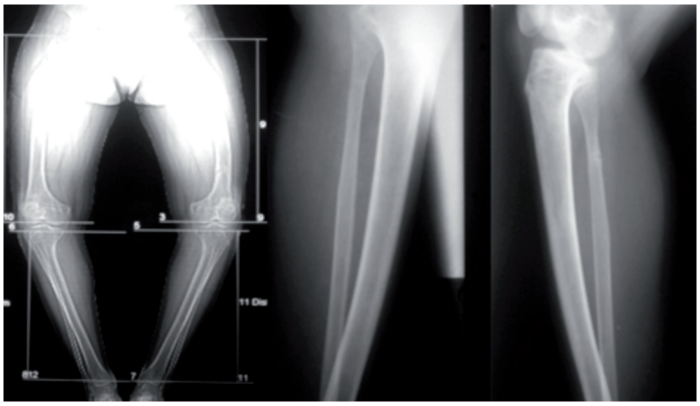

Fig. 2-A. — Pre operative C.T. scanogram and X rays.

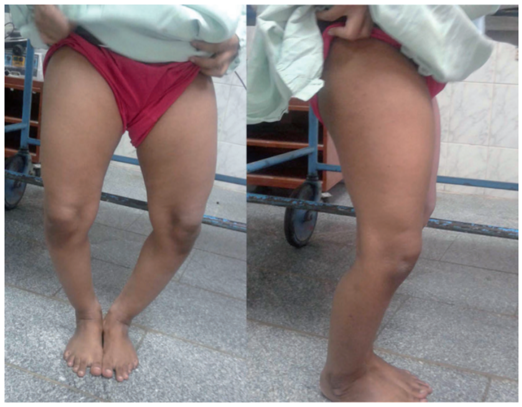

Fig. 2-B. — Pre operative photos for both lower limbs.

All patients underwent preoperative full-length standing anteroposterior radiographs of both lower extremities and lateral radiographs of the involved tibia, in addition to C.T. scanogram. The methodology described by Paley *(11)*, was used for deformity analysis. Frontal plane analysis consisted of measurement of the mechanical axis deviation (MAD), mechanical lateral distal femoral angle (mLDFA), mechanical medial proximal tibial angle (mMPTA), and proximal posterior tibial angle (PPTA). We calculated the degree of angular deformity by drawing the mechanical axis of the tibia above and below the centre of rotation and angulation (Fig. 1A, 2A, 2B).

Surgical technique

All operations were done under spinal anesthesia without use of tourniquet .

Fibular osteotomy was first done at the middle third of the fibula. Then we began to assemble a proximal tibial ring of suitable size in perpendicular orientation to the proximal tibia in both sagittal and coronal planes under guide of image intensifier. The proximal ring was fixed by 3 wires and augmented by addition of 6mm Schanz screw above the ring connected with rancho cube.

We then made the master tab of the proximal ring in the centre of the bone as it corresponds to the tibial tuberosity, we also tried to centralize the leg inside the proximal ring with clear areas in all directions for fear of oedema.

Similarly, the distal reference wire was then inserted parallel to the distal tibial articular surface and perpendicular to the distal tibia followed by application of the distal ring. Both rings were then connected by the six struts .The proximal ring was considered as the reference ring and the distal as the follow.

We then disconnected the anterior two struts from the distal ring and a transverse high tibial osteotomy was done below the tibial tuberosity. The struts were then reconnected (Fig. 2C).

Post-operative assessment

Post-operative AP and lateral X rays were obtained at a distance of 90 cm for calculation of magnification. The x ray film must get the whole rings in both views.

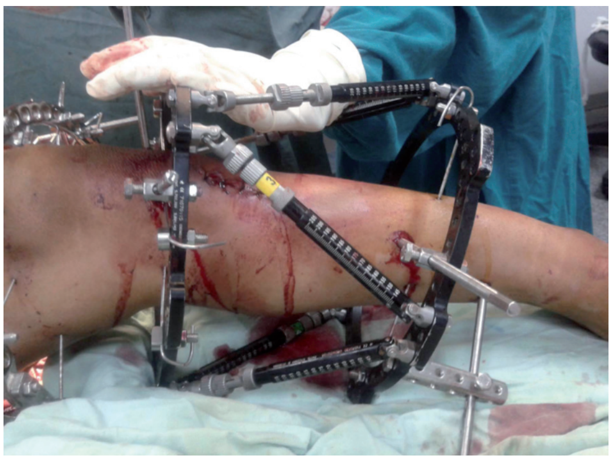

Fig. 2-C. — Intra operative photo showing apparatus assembly and the osteotomies.

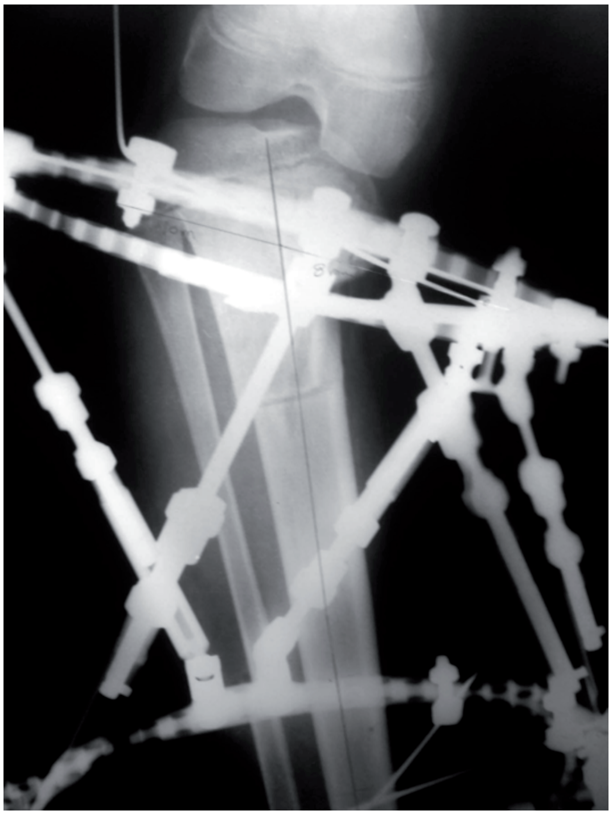

Fig. 1-B. — Post operative X rays before beginning of correction.

We drew the anatomical axis of the operated tibia both proximal and distal to the deformity in both A.P and lateral views. We measured the width of the proximal ring and mark its centre upon the x ray films.

We measured the distance between the anatomical axis of the tibia and the centre of the proximal ring to get the ring offset whether medial or lateral, and then we measured the distance between the centre of the proximal ring and the osteotomy site to get the vertical offset of the reference ring.

Clinically we calculated the amount of tibial torsion, and recorded the length of the struts from no 1 to no 6.

The angle of deformity was calculated on the preoperative scanograms in both anteroposterior and lateral views and rechecked on post-operative X rays.

All the data was then put in the TSF software application. The operating mode used was total

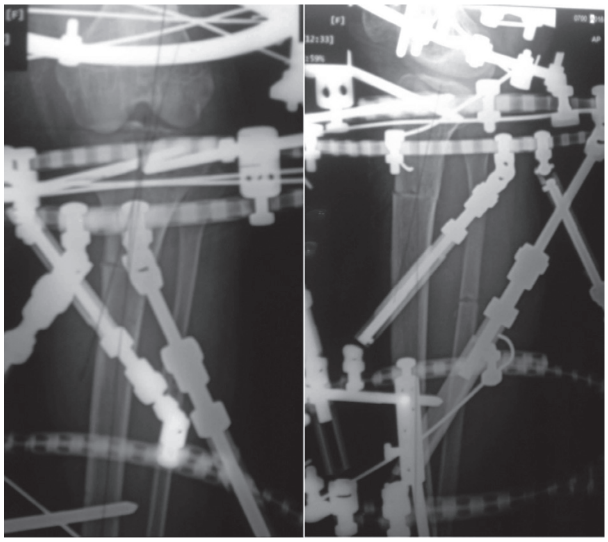

Fig. 2-D. — Post operative X rays before beginning of correction.

residual method for correction of the deformity, and we got the correction plan that we follow. (Fig. 1B, 2D)

Fig. 1-C. — Follow-up X rays after beginning of correction and changing of the struts by Illizarov rods.

Fig. 1-D. — Follow-up X rays and clinical photos 11 months post operative.

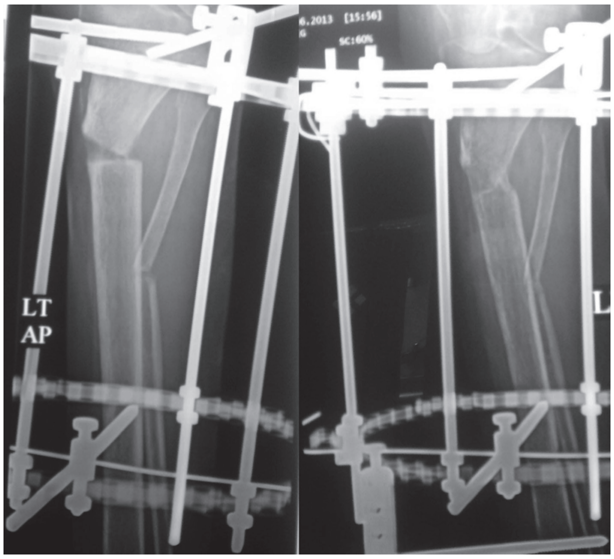

Fig. 2-E. — Follow-up X ray after change of the struts by Illizarov rods.

The correction began 4 to 5 days after doing the osteotomy, the patients were daily observed to evaluate the varus and rotation correction. All patients were admitted at the hospital till full correction was achieved. After full correction, the struts were replaced by illizarov rods to allow their use in other patients (Fig. 1C, 1D, 2E, 2F, 2G).

Patients were then followed up in outpatient clinic every two weeks till tricortical consolidation was observed when the frame was dynamized then removed two weeks later.

Fig. 2-F. — Photo after full correction of the deformity.

The clinical data were recorded on a report form. These data were analyzed using the computer program SPSS version 16. In the statistical compari-

Fig. 2-G. — Follow-up X rays and clinical photo 1 year after the operation.

son, the significance of difference was tested using Wilcoxon non-parametric test to compare mean of two variables of quantitative data. A *P* value <0.05 was considered statistically significant (S), and P value <0.01 was considered highly significant (HS) in all analyses.

RESULTS

The average follow-up period was 15 (±2) months, and the average time in the frame was 123.5 (±25.5) days (Table II).

The mean post-operative mPTA was 87(±4) degrees (range 81 to 93 degrees), where the mean preoperative mean mPTA was 68(±9) degrees (range 49 to 77 degrees) (p value 0.003).

The mean postoperative MAD was 12.2(±11.4) mm, range (-1 to 26 mm), where preoperative mean MAD was 75.7(±14.7)mm, range (60 to 107mm) (p value 0.003).

The mean postoperative PPTA was 80(±2) degrees, range (77 to 83 degrees), while the preoperative mean PPTA was 72(±12) degrees, range (42 to 82 degrees) (p value 0.028).

Table II. — The pre operative and post operative, medial proximal tibial angle (M.PTA) in degrees, mechanical axis deviation (MAD) in mm, proximal posterior tibial angle (PPTA) in degrees

	Pre operative degrees	Post operative Degrees	Wilcoxon test	P value
MPTA	67.91±8.68	87.18±3.97	2.94	0.003
MAD	75.73±14.7	12.18±11.36	2.94	0.003
PPTA	72.45±11.67	80.18±1.83	2.19	0.028

Complications

Pain was reported in all cases especially at the beginning of correction, and it was controlled by analgesics in form of NSAIDs.

Pin tract infection was found in all cases and it was of superficial type, and we reported only one case of deep infection at the site of fibular osteotomy, the infection was subsided by administration of intravenous 1st generation cephalosporin for 5 days , then oral ciprofloxacin for another 10 days.

Long hospital stay was one of our complications as patient's ignorance of apparatus system forced us to admit the patients for long period till full correction was obtained.

Knee range of motion was normal in all cases except one case who had simultaneous femoral lengthening. After physiotherapy knee range of motion was limited to 85 degrees of flexion and full knee extension.

No refracture at the site of osteotomy were encountered.

DISCUSSION

Tibia vara is frequently a multiplanar deformity of the tibia that includes varying degrees of proximal tibial varus, procurvatum, internal tibial torsion, and limb shortening. distal femoral varus and distal tibial valgus deformities can also occur in more severe cases. Tibia vara can be classified into early-onset or late-onset types depending on the age at which the deformity develops *(9,13)*.

Early-onset, or infantile, tibia vara occurs before the age of 4 years, whereas late-onset tibia vara occurs after the age of 4 years. Late-onset tibia vara can be further classified into juvenile and adolescent types.

Juvenile tibia vara develops between the ages of 4 to 10 years and adolescent tibia vara develops after the age of 10 years *(6,9)*.

Gradual correction of deformities with the use of an Ilizarov circular fixator has shown distinct advantages over the acute osteotomy in many cases. However, the use of a circular fixator involves a protracted learning curve, and the frame can often require multiple adjustments when used with multiplanar limb deformities *(10)*.

The Ilizarov fixator can correct the oblique plane deformity, but to correct the rotation a second step has to be built into the fixator or a ring-inside-another-ring construct is used. This makes the planning and execution of the three-dimensional deformity correction complex and prone to error *(8,9)*.

The Taylor-Spatial Frame (TSF; Smith & Nephew Richards, Memphis, Tenn) is a circular external fixator with 2 rings or partial rings connected by 6 telescopic struts, which uses a computer program based 6-axis deformity analysis. Since its inception, the TSF has largely been used for fractures and deformity correction in adults. Recently, the use of the frame has specifically been described for correction of infantile and adolescent tibia vara and other pediatric limb deformities *(10)*.

TSF has been shown to perform comparably to an Ilizarov fixator in treating Blount disease. Feldman et al., in another study, directly compared acute with gradual correction in 14 and 18 pediatric patients with Blount disease, respectively, and found that the patients who had gradual correction were more likely to have correction to within 3 degrees of the normal mechanical axis (94% compared with 50%) *(5,8)*.

One interesting advantage in using the TSF in the treatment of Blount disease is that it may eliminate the need for a fibular osteotomy. Eidelman et al. reported eight patients with mild to moderate adolescent Blount disease who underwent successful anatomical correction using the TSF without a fibular osteotomy *(2,8)*.

Acute correction with internal fixation does not permit partial weight bearing postoperatively and may require application of a long-leg cast. This is particularly problematic in adolescent tibia vara, as mobility is highly desirable in these obese patients. Potential complications of acute correction are numerous, including compartment syndrome, nerve palsy, malalignment, loss of correction, failure of fixation, recurrence of deformity, and leg-length discrepancy *(6,9)*.

Van Olm reported a peroneal nerve palsy in 15% of 100 patients and a compartment syndrome in 6%. Steel et al., found an 18% overall incidence of neurovascular complications *(4,15)*.

Pinkowski and Weiner, reported 11% complications, which included one delayed union and three superficial infections. They had no neurovascular complications in the 37 proximal tibial osteotomies performed for deformity correction several authors have described the use of gradual correction and ring fixators for tibia vara *(2,12,14)*.

In this case series we had no neuro vascular complication, during gradual correction or in the follow up period.

Feldman et al reported the use of TSF in 19 patients with tibia vara, 6 patients with infantile, and 13 with adolescent tibia vara.Twenty- one of the 22 tibias were corrected to within 3 degrees of normal (centre of the hip, knee and ankle aligned) with a mean frame time of 14.6 weeks. 100% of patients reported no pain at final follow-up *(8,11,16)*.

Feldman and colleagues found that gradual correction of tibia vara with the TSF was more accurate than acute correction (100% vs. 57.1%). Both the MAD and PPTA were significantly greater at latest follow-up in the Acute correction group *(1,4,11)*.

Ying Li et.al, reported the results of management of adolescent tibia vara in obese patients by T.S.F, the average medial MAD was 90mm, average mMPTA was 66 degrees (42 to78 degrees), and average PPTA was 80 degrees (75 to 82 degrees), the mean length of hospitalization after proximal tibial osteotomy and application of the TSF was 4 days (2 to 5 d). All patients healed their osteotomies. The average length of treatment time with the TSF was 114 days (80 to 166 d). At an average follow-up of 14 months (12 to 24 mo) after healing of the osteotomy, mean MAD was 10mm (0 to 30 mm), mean mMPTA was 88 degrees (85 to 92 degrees), and mean PPTA was 81 degrees (78 to 83 degrees) *(9)*.

In the current study 11 patients of adolescent tibia vara underwent correction of deformity by T.S.F. The mean post-operative mPTA was 87(±4) degrees (range 81 to 93 degrees), where the mean preoperative mean mPTA was 68(±9) degrees (range 49 to 77 degrees) (p value 0.003).

The mean postoperative MAD was 12.2(±11.4) mm, range (-1 to 26 mm), where preoperative mean MAD was 75.7(±14.7)mm, range (60 to 107mm) (p value 0.003).

The mean postoperative PPTA was 80(±2) degrees, range (77 to 83 degrees), while the preoperative mean PPTA was 72(±12) degrees, range (42 to 82 degrees) (p value 0.028).

The mean duration of fixator application was 123.5 days (85 to 166) days.

In comparison to the study done by ying li et,al, our patients stay at our hospital till correction was achieved because our patients were unable to follow up the prescribing sheets, the hospitalization time was (15 to 33 days).

Feldman reported only four complications , including cellulitis at a pin site in two patients, pin site infection requiring operative debridement in one patient and delayed union requiring 22 weeks in the frame in one patient, However, this report included patients with both infantile and adolescent Blount disease *(4,9)*.

Review of recent case series indicated that complications from TSF treatment are common; although, the definitions of minor and major complications with the use of TSF are variable across the literature. In addition, many of the complications such as superficial pin infection, neurovascular injury and joint subluxation or dislocation, for example, are inherent in treatment of complex deformities in children using external fixation *(3,8,9)*.

Superficial pin site infections requiring only oral antibiotics occur in 50-100% of patients in these reviewed series, while only, two patients among these reports experienced a deep infection requiring operative debridement, and no cases of osteomyelitis were reported *(8,9)*.

Neurovascular injury can occur from direct trauma from initial pin placement and from excessive or rapid lengthening. Complications at the corticotomy site include premature consolidation, incomplete corticotomy resulting in pain, pin stress or deformity, inadequate regenerate from rapid distraction or poor local biological factors, and fracture through the regenerate. Joint complications have been reported such as articular cartilage damage, joint subluxation, and contracture; however, these are rare *(4,9)*.

Stanitski and colleagues examined 17 patients (25 tibias) with adolescent tibia vara who underwent correction with the Ilizarov technique. Tibia varus improved from 27 degrees preoperatively to within 5 degrees of normal postoperatively. Complications included 1 premature consolidation requiring repeat osteotomy, 1 delayed union, 2 residual leg-length discrepancies, 1 residual internal tibial torsion, and 8 pin-site infections *(9,14)*.

In the current study all patients had superficial pin tract infection, only one patient had deep infection at the fibular osteotomy site that improved by administration of antibiotics. No neurovascular complications were reported in this case series.

As regard knee range of motion, it was normal in all patients except in one patient who had stiff knee because she underwent simultaneous ipsilateral femoral lengthening. She was improved by physiotherapy.

The series is limited as we have a small number of beds for such long hospital stays ,small number of very expensive T.S.F apparatus and a small number of patients with such conditions.

CONCLUSION

This series highlights the versatility and effectiveness of the TSF in the treatment of complex adolescent tibia vara.

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