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Post-traumatic multiplanar knee deformity correction using Taylor spatial frame fixator

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Original Article

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Abstract

Background
Multiplanar knee deformity needs correction in different axes; this can be achieved by the Ilizarov system, which utilizes the hinges and translation mechanism; this needs an effort or orientation and gradual correction. The Taylor spatial frame (TSF) fixator solves this problems; it consist of two rings or partial rings connecting by six telescopic struts at special universal joints.

Patients and methods
The study included six patients with complex post-traumatic knee deformity. They had genu varus, recurvatum, and shortening; two female individuals and four male individuals, with an age range from 16 to 20 years comprised our study sample. The TSF was used for correction. Mean follow-up postoperatively lasted for 10 months. All cases were assisted clinically, radiologically, and by the Lysholm and the Oxford knee scores.

Results
All patients' knee deformities were corrected by application of TSF. All patients are very satisfied; the Lysholm knee score improved from 55 to 90%. One patient has a 5° recurvatum which was compensated postoperatively without any complications. There were no leg length discrepancies.

Conclusion
The TSF fixator was able to correct a six-axes deformity and also leg length discrepancies by adjusting only strut lengths; one ring can be repositioned with respect to the other ring.

Keywords: Deformity, genu varus, knee scores, multiplanar, recurvatum, Taylor spatial frame

Introduction

The presence of a knee deformity alters the proper transmission of forces across adjacent joints in the knee and ankle. Osteotomy of the tibia can reliably correct malalignment, and one report suggests it may lead to cartilage regeneration. Achieving overcorrection with a high tibial osteotomy is important for achieving long-term success in the treatment of unicompartmental arthrosis [1,2].

A percutaneous osteotomy combined with gradual correction using the Taylor spatial frame (TSF) provides a way to correct a deformity independent of magnitude, complexity, or location. The procedure uses small incisions and minimal soft tissue stripping, and it can be used in all zones of the tibia. Without the need for complex frame modifications, the TSF can be used to correct angulation and translation in the coronal, sagittal, and axial planes around a virtual hinge, hence the term six-axes correction. The associated web-based software has simplified planning and performance of deformity correction for patients and physicians and has been used to treat all aspects of deformities in the lower extremities. Use of the TSF is associated with few complications and corrects complex tibial deformities in adults and children [1,3].

However, published studies on the TSF have been in the form of case reports, have included small numbers of patients, and

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have combined various bones and etiologies. In addition, the methods of reporting deformity correction and alignment have been variable [4,5].

Using a large series, we, therefore, asked the following questions with regard to the accuracy and outcome of knee deformity correction: (a) How accurate is the mechanical axis deviation (MAD) correction at the proximal tibia? (b) How accurate is the medial proximal tibial angle correction? (c) How accurate is the lateral distal tibial angle correction at the proximal and distal tibia, respectively? (d) What is the site of center of rotation of angulation (CORA)–CORA magnitude? (e) What are the osteotomy rules I will need? [6,7] (Figs 1-3).

Deformity correction might be acute or gradual, using internal and external fixation. The presence and proximity of the growth plate might restrict the use of internal fixation in some patients (e.g. intramedullary nailing). External fixation might be monolateral or circular [7].

Monolateral fixation is more comfortable, but correction of multiplanar deformity with a monolateral device might be very difficult.

Circular external fixation is less comfortable but more accurate in multiplanar deformity correction.

Ilyzarov external fixator was the standard fixator for deformity correction for many years. Despite many advantages, the correction of complex deformity with the Ilizarov frame requires a long learning curve, and rotational deformity with it is a difficult task [8].

TSF was introduced in 1994 and gradually became one of the most useful external fixators. Using TSF, six-axes deformity might be corrected simultaneously using a virtual hinge with computer accuracy [9,10].

Patients and methods

The study included 6 patients with complex knee deformity post-traumatic addicting proximal tibial physis mainly the antromedial part they had genu varus, recurvatum, and shortening. There were two female individuals and four male individuals, and their ages ranged from 16 to 20 rears (average, 18 years).

All patients were examined preoperatively and postoperatively using long-standing digital radiography from above the pelvis to the toes on the anteroposterior view. Lateral views of the extremities were obtained on the long-standing views and on the separate femur and tibia nonweight-bearing views [11].

(1) Drawing anatomical, mechanical axes frontal-sagittal view.
(2) The normal standard.
(3) And for our patients.

We examined all charts and long-standing radiographs before correction, at the time of the frame removal, and at least 6 months after removal of the frame. On long anteroposterior views, we recorded leg length discrepancy, MAD, lateral distal femoral angle, medial proximal tibial angle, and lateral distal tibial angle. On the lateral radiographs, we measured the posterior distal femoral angle and posterior proximal tibial

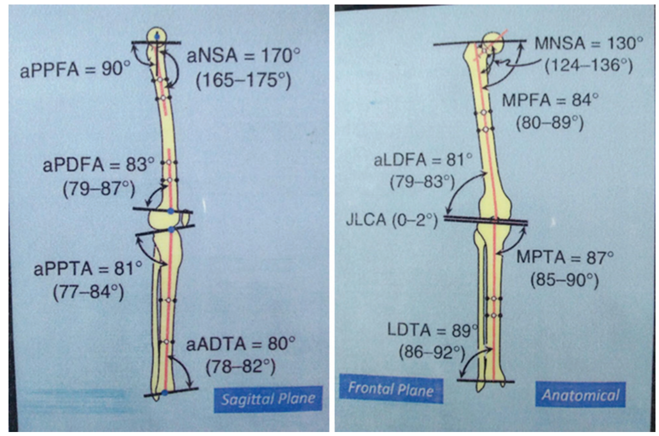

Figure 1: Normal saggital and coronal axes with joint-orientation angles.

Figure 2: Preoperative clinical photos. There was infection at the pin site in one patient and was treated successfully with no long-term sequelae.

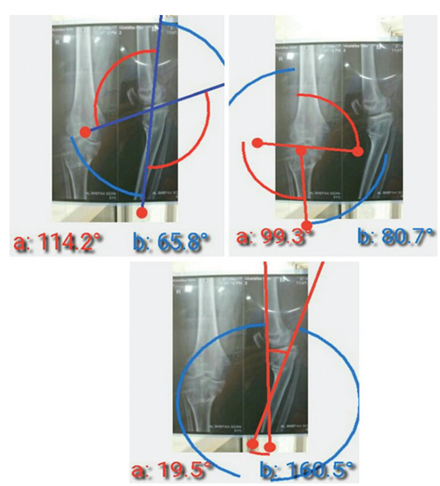

Figure 3: Preoperative radiography with different angles for deformity.

angle. Rotations were measured clinically by thigh-foot angle and position of the foot relative to an imaginary line from the center of the patella to the second toe of the foot. Correction goal was determined as correction of deformities to population average parameters of lower limbs in frontal and sagittal views and normal MAD [9,11] (Fig. 1).

TSF was used; two full rings with six struts were used for gradual correction, and one ring was distally fixed to increase stability.

All cases had a shortening range from 1.5 to to 2 cm in length. Transverse osteotomy was used transversely and rule two type at the proximal tibia. The fibular osteotomy was performed. Deformity analysis was performed according to Paley and colleagues. The mean follow-up postoperatively was 10 months (range, 8–12 months) [12,13].

All cases were assessed clinically, radiologically and by the Lysholm and Oxford knee scores [14].

Correction planning and operative technique

All operations were carried out in our hospital. Preoperative planning was carried out using the online spatial frame software. Measurement was taken from long leg standing anteroposterior radiographs. In all patients, the recurvatums varus deformity originated within the knee joint, and therefore this was where the CORA was located. Draw anatomical and mechanical axes in sagittal and frontal planes [11] (Fig. 1).

Detection of the normal standard and deviated axes.

Detection of CORA, its magnitude it was more tibial and the center of deformity in the knee joint.

We used transverse osteotomy rule 2 for correction and lengthening through callotasis, and osteotomy of the fibula was carried out intravenously, and a pneumatic thigh tourniquet was applied but not inflated. The frame was applied using the 'rings first' method. The leg was rotated so that the patella was facing forward. Using fluoroscopic imaging, a smooth 1.8-mm wire (Smith and Nephew, Memphis, Tennessee) was advanced across the proximal tibial metaphysis from laterally to medially in the coronal plane, perpendicular to the proximal tibial mechanical axis. The wire was placed at least 15-mm distal to the lateral tibial plateau in order to avoid penetrating the joint capsule. The proximal ring was centered on the leg and the wire tensioned. A 2/3 ring was usually utilized proximally to allow space for knee flexion and leg swelling. The ring was held perpendicular to the mechanical axis of the tibia in the sagittal plane. A second wire was placed anterior to the fibula head exiting the anteromedial part of the tibia. The wire was advanced in a normal fashion, while watching the foot for motion. Once the wire tip had crossed through the leg and was tenting the skin, the drill was removed and the wire tapped through. A medial face wire was placed in the same fashion, from posteromedial to exit the anterolateral tibia. The distal ring was then placed with the appropriate strut length taken into account. We predominantly used medium struts. A medial face wire was advanced posteromedially to anterolaterally across the tibia orthogonally to its long axis. Attention was paid to stretching the gastrosoleus muscles when pushing the wire down to the bone. When passing the wires, they were held with a chlorhexidine-soaked swab and advanced in a pulsed manner in order to allow heat dissipation. The distal ring was centered on the leg and fastened to the wire. The wire was then tensioned (Figs 4-8).

The standard proximal ring was placed parallel to the knee joint line. The distal tibial ring was placed parallel to the ankle joint line. The TSF positioned in the deformed manner then stabilized by many half pins and third ring distally for increase stability. And then please delete this sentence (starts were locked collections for all data, angles).

Postoperatively patients were allowed to fully weight-bear, and they were discharged on the first or second postoperative day in the majority of cases. They were seen in the clinic 1 week later. Postoperative anteroposterior and lateral radiographs in the correct rotational alignment were taken centered on the proximal ring. For the purposes of correction planning, the proximal ring was used as the reference ring, and the proximal tibiofibular joint was taken as the origin. We measured the distance from the origin to the center of the reference ring in the coronal, sagittal, and axial planes in millimeters from the radiographs. This was entered into the mounting parameters of the TSF online planning software.

Results

All patients had been corrected by application of TSF fixator.

All patients are very satisfied (criteria of satisfaction were mechanical axis through the knee. There was no limping. Lengths had been restored).

Lysholm knee score improved from 55 to 90%.

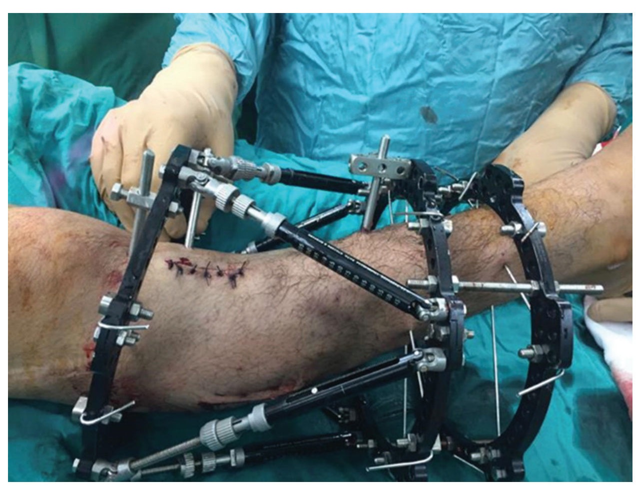

Figure 4: Intraoperative clinical photo.

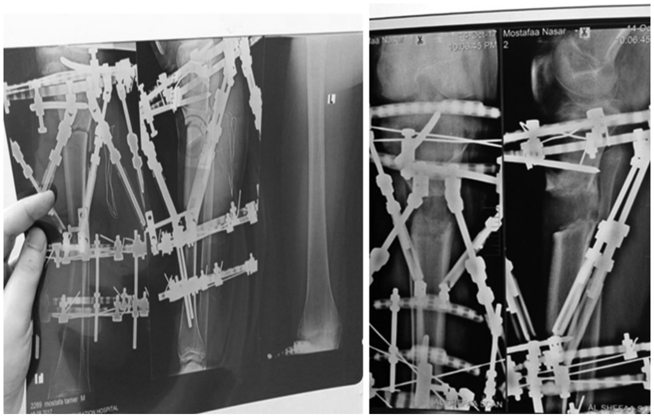

Figure 5: Radiography with TSF at the beginning and after 3 months. TSF, Taylor spatial frame.

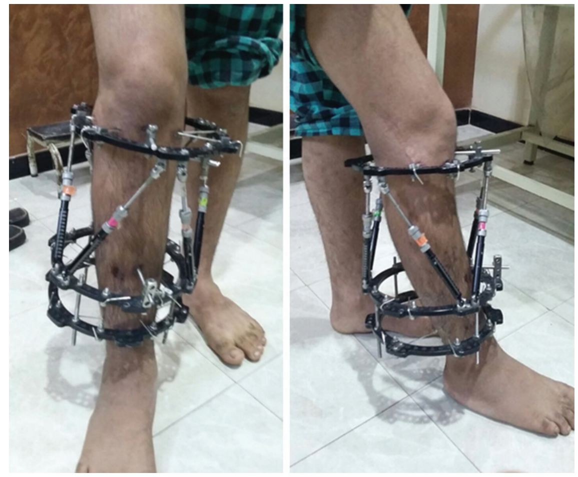

Figure 6: Clinical photos with the frame.

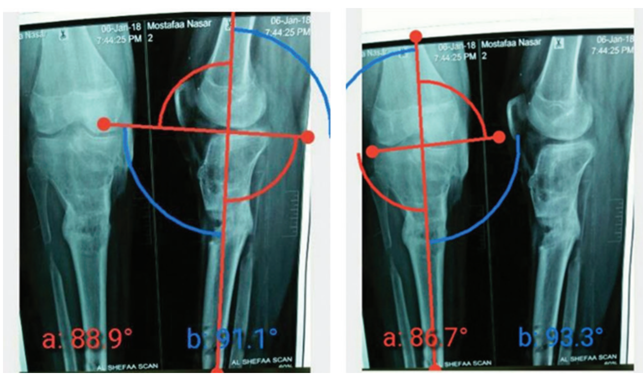

Figure 7: Postoperative radiography with different angles.

Figure 8: Postoperative clinical photos after frame removal.

One patient had a 5° recurvatm that was postoperatively compensated without amy complications.

There was infection at the pin site in one patient and was treated successfully with no long-term sequelae.

Discussion

The Ilizarov method for deformity correction and limb lengthening was the major contribution in the field of deformity correction in the last century. This method remains the basis for deformity correction using internal and external fixation [14].

The TSF enables correction of angulation and translation in the coronal, sagittal, and axial planes, enabling six-axes correction simultaneously. Contrary to the Ilizarov frame, there is no need for frequent frame adjustments and building hinges to correct multiplanar deformities. With TSF, all deformities are corrected using the same frame using a virtual hinge [14,15].

In the literature, it is reported that knee deformities lead to early onset and progress of osteoarthrosis. Deformity correction and restoration of normal joint orientation allows preventing and slowing down of the progress of the osteoarthrosis. Gradual correction using external fixation is the optimal method to manage complex femoral deformities, especially those combined with shortening or leg length discrepancy. Ilizarov has been widely used for deformity correction of long bones and has many advantages. Nevertheless, this method has limitations. Different correction constructs of Ilizarov need to be adjusted for each deformity. These procedures are very time-consuming. The computer-dependent external fixators are aimed to simplify the correction of multiple deformities. With regard to this, we asked the following questions: (a) which of the fixators provides a shorter period of femur deformity correction? and (b) which of the fixators provides better accuracy of correction [16]?

Dror Paley reported that the most important result of research is that the software-based Ortho-SUV Frame reduces the time of deformity correction compared with IA in correction of medium deformity by 1.6 times and complex deformity correction by 2.3 times. However, we did not find significant differences in the time taken for simple deformity correction [10,14,17] (Tables 1–3).

Ganger and colleagues reviewed the results of treating 22 patients with 25 post-traumatic lower limb deformities. In the patients were young adults (mean age at the time of correction was 22.7 years). Only two patients in this study had residual

Table 1: For genu varus preoperative versus postoperative medial proximal tibial angle (normal 85-90)

Patients	Age	Sex	Preoperative	Postoperative	Percentage
No. 1	16	Male	82	90	62.5
No. 2	16.5	Female	81.5	87	100
No. 3	19	Female	79	88	88.9
No. 4	18	Male	84	88	75
No. 5	20	Male	80.7	93.3	50
No. 6	20	Male	80	90	70

Table 2: For genu recurvatum preoperative versus postoperative medial proximal tibial angle (anatomical posterior proximate angle) (normal 77-84 degs)

Patients	Age	Sex	Preoperative	Postoperative	Percentage
No. 1	16	Male	100	82	94.7
No. 2	16.5	Female	103	85	81
No. 3	19	Female	95	84	78.6
No. 4	18	Male	98	82	94
No. 5	20	Male	114.2	91.1	70
No. 6	20	Male	102	98	66.7

Table 3: Computed tomography staging system for osteochondral lesions of the talus

Stage	Definition
I	Cystic lesion with intact roof
IIA	Cystic lesion with communication to the talar dome surface
IIB	Open articular surface lesion with an overlying nondisplaced fragment
III	Nondisplaced fragment with lucency
IV	Displaced fragment

CT classification of OLT [18].

MAD at the latest follow-up. Eidelman and colleagues analyzed the results of treatment with TSF of post-traumatic deformities in children and adolescents. There were 18 patients with a mean age of 13.1 years and equal numbers of proximal, medial and distal tibial malunions. In all patients, restoration of mechanical axis and length was achieved with minimal or no difference compared with anatomical parameters. Similar conclusions were arrived at in several other studies in children with fractures treated with TSF. Several studies investigated the treatment of children with limb deformities with the TSF. Naqui *et al*. reviewed 53 patients treated with 60 frames on 55 limbs. Forty limbs had no final deformities, 12 limbs had mild residual deformities, and three limbs needed further treatment. In 2006, Eidelman and colleagues reviewed the results of treatment of 31 children (44 frames) with various deformities. Most patients achieved anatomic correction of deformities and, despite many complex cases, the results were encouraging [16,19,20].

In 2010, Rozbruch and colleagues questioned whether the TSF can accurately correct tibial deformities. They retrospectively reviewed 102 patients (122 tibiae) who underwent tibial osteotomy with gradual correction with the TSF. The mean age of patients was 39 years (range, 5–72 years). This is the largest cohort of patients treated with TSF described until now in the literature. The treatment goal was overcorrection of the MAD to 6–12 mm medially or laterally, depending on the presenting problem. Gradual correction of all tibial deformities was accurate and with few complications [21–24].

In our opinion, the distinct advantages of the TSF result from the reduced necessity to build a patient-customized frame construct, from its potential for simultaneous multidimensional deformity correction and from the support of a precisely working internet-based software [25].

In our study

However, our using the TSF fixator in six patients with multidirectional knee deformities yielded us very accurate and gratifying results without major complications. The fixator is a definite advance over the older Ilizarov system, and it is easy to use.

Conclusion

Treatment with the TSF. The fixator can correct severe multiplanar knee deformities, as demonstrated in our study. TSF reduces the time of deformity correction and provides a greater accuracy of correction.

(1) The simplicity in using the hardware facilitates the correction procedures.
(2) There is no need for the surgeon to build the fixation.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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