ORIGINAL ARTICLE

Acta Orthop Traumatol Turc 2013;47(2):86-90
doi:10.3944/AOTT.2013.2958

Efficacy of the Taylor spatial frame in the treatment of deformities around the knee

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Objective: The aim of this study was to determine whether the Taylor spatial frame (TSF) can precisely correct deformities around the knee and whether application of TSF is easy and safe for treatment of the deformities around the knee.

Methods: This study included 50 retrospectively reviewed limbs of 37 patients (mean age: 23 years, range: 10 to 58 years) with deformity around the knee joint treated using the TSF. Thirty-three limbs had tibial and 17 femoral deformities. Preoperative standard anteroposterior, lateral radiographs and standing orthoroentgenographic measurements were taken for each patient. Mechanical axis deviation (MAD), leg-length discrepancy (LLD) and lateral femoral distal angle (LDFA) and medial proximal tibial angle (MPTA) were measured from standing orthoroentgenographics. All measurements were repeated after external fixator removal.

Results: The frame was applied for an average of 20.3 (range: 4 to 36) weeks. Mean follow-up time following removal of external fixator was 32 (range: 15 to 54) months. An effective and accurate correction was achieved in all cases. Solid bone consolidation was obtained in all but two cases which underwent bone grafting.

Conclusion: Taylor spatial frame appears to be a safe and effective method for the gradual correction of the complex translational and rotational deformities around the knee.

Key words: Deformity; knee; Taylor spatial frame; treatment.

Deformities located around the knee can cause deviation in the mechanical axis and malalignment of the hip, knee, or ankle which affects the load distribution of the knee. Therefore, deformities in this area must be precisely corrected.[1]

The Ilizarov circular external fixator successfully corrects limb deformities using multiple components, each designed to address specific planar deformities.[2] However, the use of a circular fixator involves a long learning curve, the frame often requires multiple adjustments when used for multiplanar deformities; residual malalignment after correcting multiplanar deformities is common.[3,4]

The Taylor spatial frame (TSF) is an external fixator system that uses the classic correction principles of the Ilizarov system along with a six-axis deformity analysis incorporated via a computer program. The TSF uses a virtual hinge and a computer system that

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Submitted: June 18, 2012 **Accepted:** January 31, 2013

Available online at
www.aott.org.tr
doi:10.3944/AOTT.2013.2958
QR (Quick Response) Code:

corrects length and all deformities including angulation, translation, and rotation.[2,5] The TSF has been used for both tibial and femoral deformities.[6,7]

The purpose of this study was to report the results of patients who were treated for deformities around the knee with the TSF.

Patients and methods

We retrospectively reviewed 50 limbs of 37 patients (21 male, 16 female; mean age: 23 years; range: 10 to 58 years) who were treated for deformities around the knee with the TSF (Smith & Nephew, Inc., Memphis, TN, USA) between 2005 and 2009. Thirty-three limbs had tibial deformities and 17 femoral deformities. Twenty-six were left-sided and 24 were right-sided.

Etiologies involved congenital deformities (9 cases), metabolic bone disease (8 cases), growth arrest (9 cases), malunion (6 cases), complications due to cosmetic lengthening (2 cases), poliomyelitis sequelae (2 cases), and polyostotic fibrous dysplasia (one case).

Primary tibial limb deformities included 13 varus, 12 valgus, 2 oblique plane, 2 recurvatum, 3 procurvatum and 8 translational deformities. Secondary tibial deformities included 7 with internal rotation, 6 with external rotation and 17 with limb-length deformities. Primary deformities of the femur consisted of 9 valgus, 6 oblique plane, 1 varus deformity and 15 translational deformities. The secondary femoral deformities included 10 with internal rotation, 4 with external rotation and 9 with limb-length inequalities. All deformities were analyzed for translation, frontal angulation, and deformities on sagittal and axial planes.

Preoperative standard anteroposterior, lateral radiographs and standing orthoroentgenographic measurements were taken of all patients. Mechanical axis deviation (MAD), leg-length discrepancy (LLD), lateral femoral distal angle (LDFA) and medial proximal tibial angle (MPTA) were measured on standing orthoroentgenographs. Rotational deformity was measured clinically and/or using computerized tomography (CT). All performed measurements except CT were repeated after external fixator removal (Fig. 1).

Operations were performed with the patient in the supine position on a radiolucent table. The majority of osteotomies were performed percutaneously using the Gigli saw technique and special insertion guides using the multiple drill-hole technique. Osteotomies were performed in the proximal tibia in 33 limbs and the distal femur in 17.

We used the 'total residual mode' (ring-first method) deformity correction. In this method, rings are applied in the most suitable position perpendicular to all segments and a correction is established when the rings are parallel to each other. The frame was applied with K-wires and 6-mm hydroxyapatite-coated pins. Thirteen measurements, including deformity, mounting and frame parameters were taken and entered into a software program to obtain the correction plan.

The correction procedure began on the 5th postoperative day and patients were discharged on the same day. Patients were encouraged to bear full weight using crutches.

Follow-up visits were scheduled weekly during the correction period. The amount of correction was determined based on radiological and clinical examinations. The TSF was removed after total consolidation was observed on anteroposterior and lateral radiographs (Fig. 1).

Results

Mean time in the frame was 20.3 (range: 4 to 36) weeks. Average follow-up time from removal of external fixator was 32 (range: 15 to 54) months. Plating after lengthening was performed in three cases and nailing after lengthening was performed in three after deformity correction with the TSF.

Solid bone consolidation was obtained in all but two cases which subsequently underwent bone grafting.

The tibial MAD correction was accurate. Patients with a varus tibial deformity had a preoperative mean MAD of 56 (range: 16 to 109) mm. The target value of MAD is 0. Patients with a valgus tibial deformity had a preoperative MAD average of 37 (range: 23 to 86) mm. MAD was corrected an average of 5 mm medial and 5 mm lateral to the midline.

Patients with femoral deformities had an average MAD of 65 (range: 23 to 100) mm and all patients with a MAD deformity were corrected an average of 5 mm medial and 5 mm lateral to the midline.

The MPTA and LDFA were corrected accurately for tibial deformities and femoral deformities. The MPTA of patients with tibial valgus deformity improved from a mean of 95° (range: 92 to 99°) to 87.5° (range: 85 to 89°), and the MPTA of those with varus deformity improved from 75° (range: 5 to 81°) to 88.2° (range: 8 to 90°).

Lateral femoral distal angle corrections were accurate for the femoral deformities. The LFDA improved from a mean of 74.2° (range: 6 to 84°) to 87.6° (range: 8 to 90°).

Mean limb lengthening of 25 (range: 12 to 60) mm was obtained in 26 limb (18 tibia, 8 femur) segments.

External fixation time for these limbs was 20.4 (range: 4 to 30) weeks.

Complications included a recurrence of deformity in two cases and nonunion at the distraction side in two cases. Some cases had pin-side problems, such as a superficial infection, but none required additional surgery.

One case of metabolic bone disease with bilateral tibial and femoral complex deformities was treated with bilateral tibial osteotomies as a first procedure, but the patient was lost to follow-up and the final result was knee-joint malorientation.

Discussion

The Ilizarov technique uses distraction rods and hinges to treat long-bone deformities.[8] The correction of single-plane deformities is eased by the Ilizarov external fixator as the hinges and translational parameters are specifically oriented for multiplanar deformities. The TSF, an external fixator system that uses the classic correction principles of the Ilizarov system, allows simultaneous correction of six axes of deformities without a frame modification.[9] The TSF is also useful for both tibial[6] and femoral deformities.[7] We investigated the use of TSF for both femoral and tibial deformities around the knee.

The goal of treatment for femoral and tibial deformities around the knee is to provide proper alignment and joint orientation, obtain the correct mechanical axis, equalize limb lengths and encourage functional restoration.[10] Femoral and tibial deformities can be corrected by osteotomy and internal fixation or osteotomy and external fixation. Acute or gradual correction may be used to manage these types of deformities.[11]

In the femur, we corrected 6 oblique plane deformities with a mean of 24° (range: 18 to 30°), 9 valgus deformities with a mean of 22° (range: 12 to 30°) and an aver-

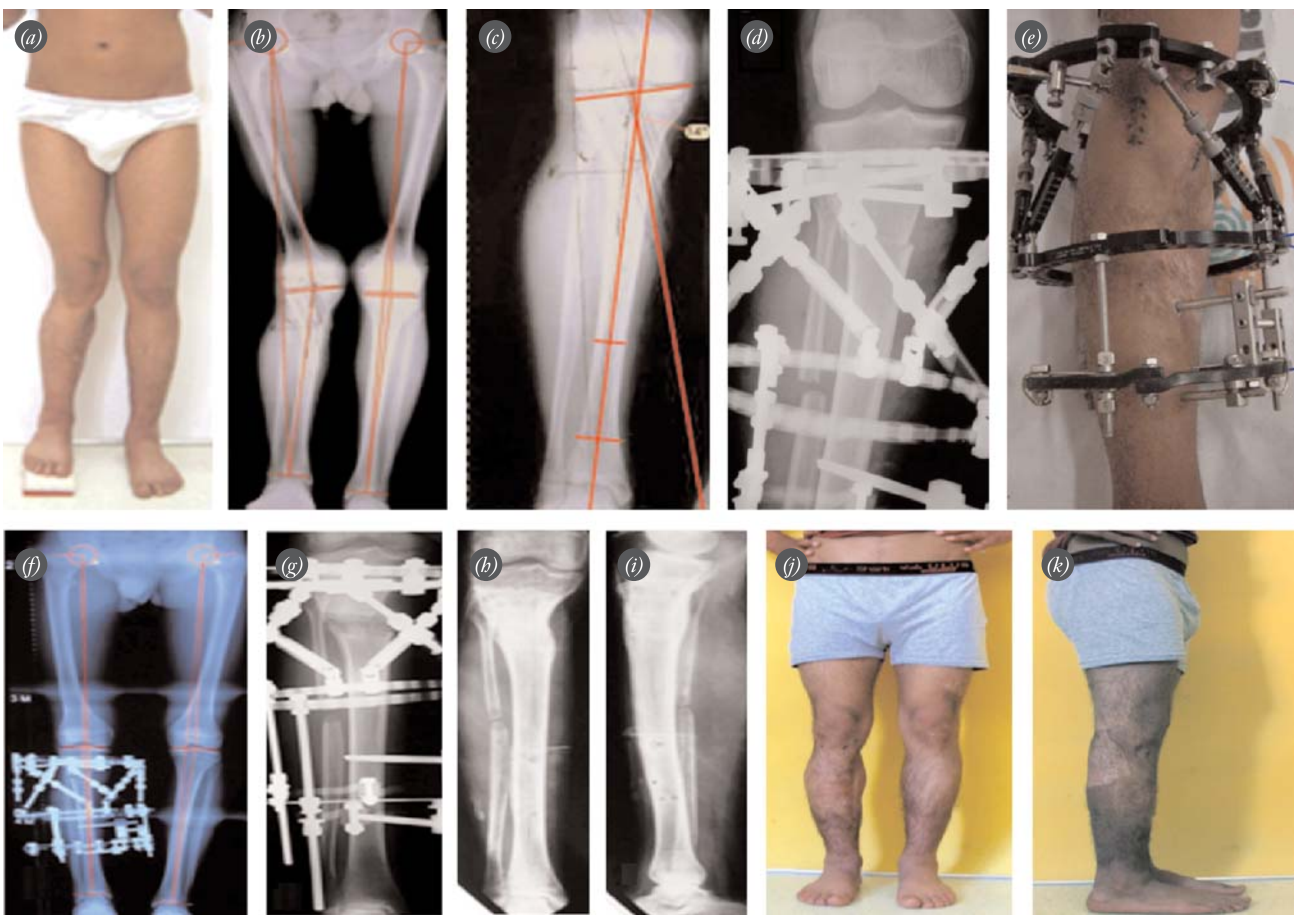

Fig. 1. Images of a 14-year-old patient with Type 3A open tibial fracture and Type 2 epiphysiolysis after a traffic accident in 2004. **(a)** Preoperative clinical view. **(b)** Orthoroentgenograph of the patient: right mLDFA=87°, MPTA=103°. **(c)** Anteroposterior radiograph showing 14 degree valgus alignment. **(d)** Early postoperative radiograph. **(e)** Early postoperative clinical view. **(f)** Orthoroentgenograph of the patient after correction: right mLDFA=87°, MPTA=87°. **(g)** Anteroposterior radiograph of the tibia after correction. **(h, i)** Postoperative radiographs. **(j, k)** Postoperative clinical views. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

age 10.4 mm of translation (range: 5 to 20 mm). Marangoz et al. reported a mean of 15° (range: 4 to 40°) of genu valgum and 11.9° (range: 3 to 23°) of genu varum deformities in 22 femurs.[6] Sluga et al. treated 4 femoral deformities with the TSF and obtained a mean valgus correction of 9.7 and a lateral translation of 7.5 mm.[12]

The mean external fixation time for the femoral deformities was 19.4 (range: 4 to 30) weeks. Eidelman et al. reported a mean external fixation time of 14.1 (range: 9 to 24) weeks.[9] Sluga et al. reported that the mean frame-application time to manage lower-limb deformities in children was 40 (range: 23 to 52) weeks.[12] Marangoz et al. reported a mean frame time of 24 (range: 9 to 76) weeks.[6]

In the current study, corrected tibial varus deformities had a mean of 24° (range: 11 to 40°), a corrected mean tibial valgus deformity of 15° (range: 4 to 23°) and an average translation of 8.3 (range: 5 to 16) mm. Feldman et al.[2] used the TSF in 11 tibial malunions and seven tibial nonunion cases. They corrected a mean angulation of 20.6° (range: 8 to 62.4°) and reported 17 achieved unions and significant correction of deformities. Fadel et al. reported an average sagittal angulation correction of 15.6 (range: 0 to 22) mm and lateral translation of 7.8 (range: 2 to 16) mm along with excellent TSF results in 5 of 6 patients.[13] Rozbruch et al.[7] reported on a large series of tibial deformities including 122 tibial deformities and 84 proximal tibial deformities. They concluded that a gradual tibial correction using the TSF is safe and precise.

The mean external fixation time for the tibial deformities in our study was 21 (range: 12 to 30) weeks. Feldman et al. reported a mean external fixation time of 18.5 (range: 12 to 32) weeks in their tibial malunion and nonunion cases.[2] Fadel et al. reported that the mean time to manage lower-limb deformities in 22 patients was 5.2 (range: 2 to 9) months.[13] Ganger et al. reported a mean frame time of 6 months (range: 2.1 to 10.6) months.[14]

In the current study, we treated 27 rotational deformities on the tibia and femur (13 tibial and 14 femoral deformities). In the tibia, we corrected the internal rotation in 6 patients by a mean of 13.3° (range: 10 to 20°) and the external rotation in 7 patients by a mean of 25.2° (range: 7 to 45°). Rozbruch et al. corrected 38 internal rotations with a range of 5 to 40° and 45 external rotations with a range of 5 to 30° in tibial deformities.[7] Additionally, in this study, 10 internal rotations of the femur with a mean of 24.7° (range: 15 to 40°) and 4 external rotations of the femur with a mean of 16.2° (range: 10 to 25°) were treated.

In the literature, the timing of distraction or correction application is controversial. Several authors started correction 7 days after surgery,[6,15] at the postoperative 6th or 10th day,[7,9] while others suggest application between the 5th and 7th day.[14,16] In this study, we begun correction 5 days following surgery and had no consolidation complications.

The most common complications experienced in this study were pin-side problems such as infection or loosening. Almost all patients had pin-side problems but none required additional surgical procedures. Knee stiffness is another complication found in femoral applications although none of our patients with knee stiffness required physical therapy. Marangoz et al. reported two cases of posterior knee subluxation treated with soft-tissue release and aggressive physical therapy.[6] We did not find any knee posterior subluxation in any of the femoral applications. Another complication is fracture following frame removal. Eidelman et al. reported two fractures after removing the frame.[9] In our series, no patient experienced fracture after frame removal although two patients underwent bone grafting due to nonunion. Feldman et al. reported one case of nonunion leading to premature removal of the frame.[2] In the current study, we experienced a deformity recurrence in one patient with Turner syndrome in which the deformity relapsed during growth.

Limitations of our study include its retrospective design and patient selection and wide variety in patient ages.

In conclusion, our study showed that TSF is a safe and effective method for the gradual correction of the complex translational and rotational deformities around the knee.

Conflicts of Interest: No conflicts declared.

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