Journal of Pediatric Orthopaedics
23:387–391 © 2003 Lippincott Williams & Wilkins, Inc., Philadelphia

Correction of Tibia Vara With Six-Axis Deformity Analysis and the Taylor Spatial Frame

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Summary: Operative correction for infantile and adolescent tibia vara has been described using both external and internal fixation. Gradual correction using a circular fixator offers the advantage of accurate coronal, sagittal, and axial plane correction without significant soft tissue dissection. This study evaluated the use of six-axis deformity analysis and the Taylor Spatial Frame (TSF) for the correction of tibia vara. Nineteen patients (22 tibias), 6 with infantile and 13 with adolescent tibia vara, underwent correction with TSF. On the basis of mechanical axis correction, 21 of 22 tibias were corrected within 3° of normal. Using Schoenecker's criteria, all patients achieved good results (no pain, <5° difference in tibial-femoral angle from the normal side). Complications included one intractable pin-site infection, two superficial pin-site infections, and one delayed union. Six-axis deformity analysis and TSF provide accurate and safe correction of infantile and adolescent tibia vara. **Key Words:** Blount's disease—External fixator—Taylor Spatial Frame—Tibia vara.

Osteotomy for infantile and adolescent tibia vara (1,2) 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 (8). Use of a circular frame has demonstrated the ability to gradually correct angulation, translation, rotation, and shortening, thus minimizing these complications. Ilizarov circular frames have been used previously (4,14,23). The purpose of this study was to evaluate the use of six-axis deformity analysis and the Taylor Spatial Frame (TSF) for correction of tibia vara.

MATERIALS AND METHODS

The TSF was used in the chronic mode. Every deformity was analyzed with the following six axes: AP view angulation (varus/valgus), lateral view angulation (procurvatum/recurvatum), axial view angulation (internal/external), AP view translation (medial/lateral), lateral view translation (anterior/posterior), and axial view translation (short/long). After inputting the deformity and mounting parameters, the strut lengths were determined by the computer and the frame was constructed in a manner replicating the deformity. Gradual correction was achieved through the lengthening or shortening of the struts until the two rings were parallel. If a residual deformity existed, then the six-axis deformity analysis was performed again and the correction was achieved by adjusting the struts accordingly.

All patients had standing patella-forward full-length AP and lateral radiographs of both limbs for the measurement of mechanical axis deviation (MAD), femoral deformity, and joint laxity. The tibial deformity was calculated on patella-forward AP and lateral tibia views using the method of Paley et al. (15). Additionally, patients with infantile tibia vara had intraoperative knee arthrograms to outline the femoral condyles and tibial plateau accurately. These were then used to calculate the deformity of the tibia. Assessment of rotation was done clinically by examining the thigh–foot axis in prone position and comparing the patella and bimalleolar axis.

The deformity was analyzed using the proximal fragment as the reference fragment. The origin on the reference fragment and corresponding point on the deformed distal fragment were identified on the preoperative radiographs. The frame parameters, mounting parameters, and deformity parameters were calculated and entered into the computer software. The neutral frame height was then calculated depending on the limb length. Mounting parameters were recalculated in the operating room after placement of the proximal ring.

Patients underwent surgery on the day of admission. All surgeries were performed under general anesthesia,

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None of the authors received financial support for this study.

and deformity correction commenced 7 days after surgery. Three patients had bilateral corrections as staged procedures. The second operation on the contralateral tibia was performed at the time when the previous spatial frame was removed from the corrected tibia. Patients were administered prophylactic perioperative antibiotics. Tourniquet was not used during the procedure. The osteotomy was performed with multiple drill holes and an osteotome. Patients had a suction drain at the tibial osteotomy site that was removed between 24 and 48 hours after the operation. One patient had simultaneous percutaneous lateral proximal tibial physis epiphysiodesis to prevent recurrence of varus deformity due to the closure of proximal medial tibial physis. Patients were discharged weight-bearing as tolerated with crutches or a walker. Radiographs were taken at 2 weeks to be certain that the osteotomy was moving, and then after completion of correction. The fixator in the consolidation phase of correction was maintained until three-cortices osseous healing.

Results were graded according to the mechanical axis correction (15) and Schoenecker's criteria (19): good = no pain, <5° difference in tibial-femoral angle from the normal side; fair = the same radiographic criteria with occasional pain; and poor = pain restriction of activity, radiologic residual deformity (over- or undercorrection), or joint narrowing.

RESULTS

Between 1998 and 2000, 19 patients (22 tibias), 13 boys and 6 girls, underwent correction of tibia vara with the TSF. The mean age of the patients was 9.9 years (range 3–16 years). Six patients (8 tibias) had infantile tibia vara. Two of the infantile cases were bilateral. One patient had recurrence from a previous osteotomy done 4 years before. Two tibias were Langenskiöld Stage II, three were Langenskiöld Stage III, and two were Langenskiöld Stage IV. One tibia was Langenskiöld Stage V; the patient underwent a concurrent lateral proximal tibial hemiepiphysiodesis. Thirteen patients (14 tibias) had adolescent tibia vara. The mean body weight was 64.3 kg (range 22–88 kg), and the mean height was 123 cm (range 66–186 cm). All the patients exceeded their ideal body weight by at least 50%.

The mean follow up was 2.8 years (range 2–3.8 years). The mean operative time was 2.5 hours (range 2–4 hours). The mean hospital stay was 5.2 days (range 3–9 days). A fibular osteotomy was performed in 17 of 22 cases. The duration of frame fixation from the time of application to the time of removal averaged 14.6 weeks (range 9–24 weeks). Patients were corrected on average 1 mm and 1° per day.

Preoperatively, the mean magnitude of the tibial deformity was 20.5° (range 11.3°–53.8°). The mean oblique plane deformity was anterolateral 31° (range 0°–62°) from the coronal plane. The mean lateral distal femoral angle was 88.0° (range 87°–90°).

Mean preoperative to postoperative changes (Table 1) were medial proximal tibial angle from 71.4° (range 38°–80°) to 87.9° (range 84°–90°), proximal posterior tibial angle from 71.8° (range 60°–83°) to 80.9° (range 78°–84°), MAD from 53.9 mm (range 31–120 mm) to 1.4 mm (range 0–4 mm), varus from 16.5° (range 8°–50°) to 0° (range −2° to 2°), and procurvatum from 12.2° (range 2°–21°) to 0.1° (range −2° to 3°). Six tibias had clinical internal rotation deformity with a preoperative mean of 17.5° (range 10°–30°) and no postoperative clinical evidence of internal rotation. Shortening was present in 18 patients, with a preoperative mean of 11 mm (range 3–30 mm) and postoperative correction within 2 mm. Twenty-one of 22 tibias were corrected to within 3° of normal values in both the coronal and sagittal planes. One tibia had a residual 4° of varus at last follow-up. There were 2° or less of overcorrection in four tibias (shown as negative sign in Table 1). No persistent joint laxity was present postoperatively. As per Schoenecker's criteria (17), there were 100% good results in terms of pain and radiographic criteria in our patients.

The preoperative through postoperative clinical appearance and radiographs of an 8-year-old girl with recurrent oblique plane tibial deformity treated with the TSF are presented in Figures 1 through 6.

TABLE 1. *Preoperative and postoperative deformity as measured on radiographs*

	Preoperative mean (range)	Postoperative mean (range)
LDFA in degrees	88.0 (87–90)	88.0 (87–90)
MPTA in degrees	71.4 (38–80)	87.9 (84–90)
PPTA in degrees	71.8 (60–83)	80.9 (78–84)
MAD in millimeters	53.9 (31–120)	1.4 (0–4)
Varus in degrees	16.5 (8–50)	0 (−2 to 2)
Procurvatum in degrees	12.2 (2–21)	0.1 (−2 to 3)

LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; PPTA, posterior proximal tibial angle; MAD, mechanical axis deviation.

FIG. 1. Preoperative clinical deformity.

FIG. 2. A: Preoperative AP radiograph. **B**: Preoperative lateral radiograph.

FIG. 3. During limb lengthening and deformity correction.

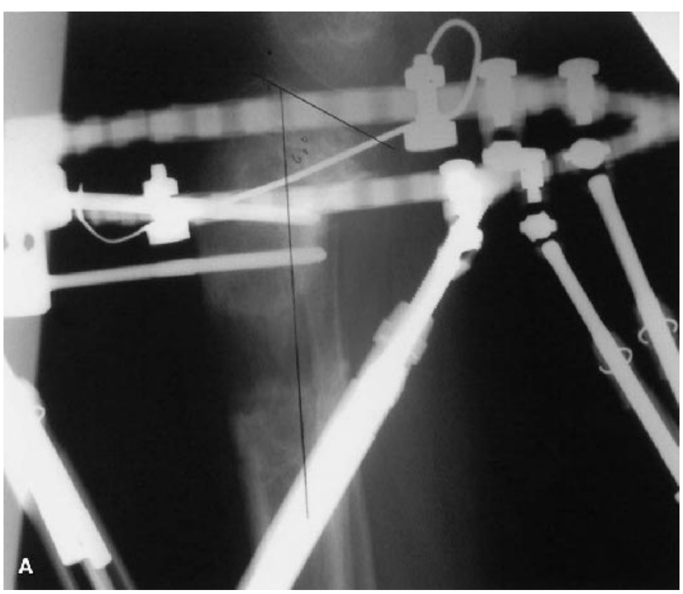

FIG. 4. A: After lengthening, before residual procurvatum deformity correction. **B**: After residual procurvatum correction.

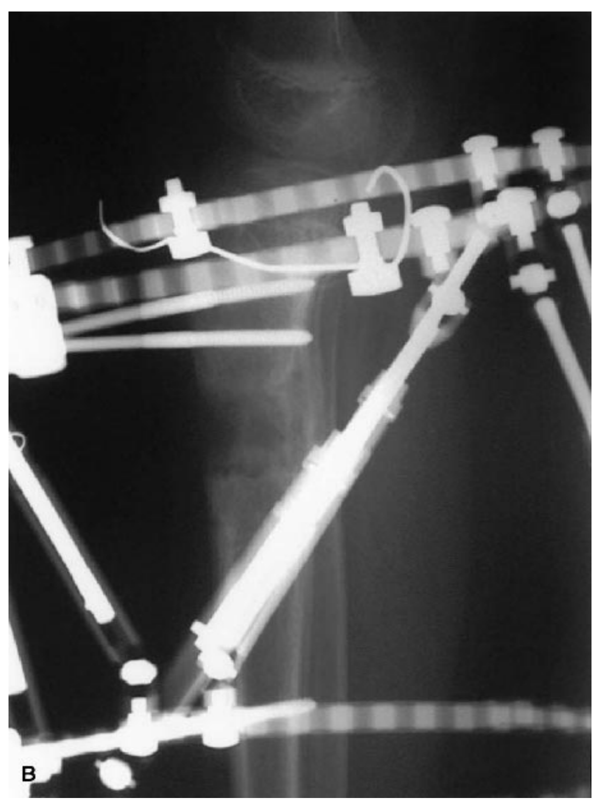

FIG. 5. A: AP radiograph after frame removal. **B**: Lateral radiograph after frame removal.

There were four complications (18%). One patient required a debridement of pin sites under general anesthesia for intractable pin-site infection. Two patients required intravenous antibiotics for cellulitis associated with pin-site infection. One patient had delayed union, which required 22 weeks of frame fixation. No cases of osteomyelitis, non-union, knee or ankle malorientation, compartment syndrome, or nerve palsy occurred. Bone grafting was never required. When one patient was going into rotational malalignment, his struts were adjusted in the clinic and he had no residual deformity.

DISCUSSION

Several surgical procedures have been described for the treatment of tibia vara, including proximal tibial osteotomy, hemiepiphysiodesis, asymmetric physeal distraction, and elevation of medial tibial plateau (3,5–8,10–12,18,19,21,22,26). Acute correction of a proximal tibial osteotomy can be associated with significant complications. The rate of neurovascular complications has been reported to range from 3.3% to 18% (9,10,13,16,17,24,27). Acute correction has been associated with peroneal nerve palsy and compartment syndrome. Van Olm and Gillespie (Canadian Orthopaedic Association Meeting, Quebec, Canada, 1983) reported a peroneal nerve palsy in 15% of 100 patients and a compartment syndrome in 6%. Steel et al. (24) found an 18% overall incidence of neurovascular complications. Price et al. (17) described the use of a uniplanar dynamic fixator for 34 osteotomies in 25 patients for correction of tibia vara. They had six tibias with residual varus, two patients with a postoperative neuropraxia, and nine pin-tract infections. Pinkowski and Weiner (16) 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 (4,14,20,23) have described the use of gradual correction and ring fixators for tibia vara. 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. Stanitski et al. (23) reported eight patients who had superficial pin-site infections. There was one delayed union, one premature consolidation that required re-osteotomy, two residual limb length inequalities (1.8 and 3.0 cm), and one failure to correct rotation.

This is the first report describing treatment of tibia vara using gradual correction and six-axis deformity analysis for correction with the TSF and computer-assisted software (25). We have successfully treated infantile tibia vara and adolescent tibia vara with the TSF. The TSF uses a six-axis analysis method to calculate the three-dimensional deformity and correct the deformity (i.e., varus/valgus; procurvatum/recurvatum; clockwise/anticlockwise rotation in all dimensions). Of note, we chose the level of the proximal tibia-fibula joint as the origin and therefore did not osteotomize the fibula in our last five cases. As well, in only three cases (all infantile tibia vara) was rotation used as an independent axis of correction, and therefore most cases of tibia vara have no rotary component. The oblique plane deformity mimics internal rotation.

We had no wound infections. Three patients had pin-tract problems. Our low incidence of pin-tract infections may be related to our liberal use of postoperative anti-

FIG. 6. Postoperative clinical picture.

biotics. Patients were often kept on antibiotics during the corrective phase and then told to keep a bottle of cephalexin at home. If a pin became painful or had increased drainage, patients were instructed to begin antibiotics again. This may lead to a decreased reporting of pin-tract problems. There was one patient with a delayed union. We did not perform prophylactic fasciotomies and had no compartment syndromes or neurologic injuries.

We found the TSF technique simple, accurate, and reproducible. Previously, during acute correction we found use of the fluoroscopic centering of the Bovie cord over the hip, knee, and ankle, as a method of correction of mechanical axis deviation, difficult to use. It also may give erroneous results because one may obtain good mechanical axis correction but have significant malorientation of the joint line. This is particularly true if there is a femoral deformity present or if the osteotomy is performed far from the site of the deformity. The gradual correction allowed for confirmation of the mechanical axis and joint line correction through full-length femur and tibia radiographs. Residual correction required no return to the operating room and therefore less morbidity for the patient and little work for the surgeon.

Based on our results, we think that the TSF allows safe gradual correction and is accurate and well tolerated. Our results compare favorably with the published literature. Despite this potentially difficult group of patients, the results overall were good, with minimal morbidity. We now use the TSF as the first line of treatment of infantile and adolescent tibia vara.

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