Accuracy of Correction of Tibia Vara

Acute Versus Gradual Correction

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Abstract: The purpose was to assess the accuracy of deformity correction achieved in patients with tibia vara using acute intraoperative correction compared with gradual postoperative correction. Acute correction (AC) group consisted of 14 patients (14 tibiae) with a mean age of 11.4 years and whose tibia vara was corrected acutely and held using an EBI external fixator. Gradual correction (GC) group consisted of 18 patients (18 tibiae) with a mean age of 10.2 years and whose tibia vara was corrected gradually using 6-axis deformity analysis and Taylor Spatial Frame. Deformity measurements were compared preoperatively, postoperatively, and at latest follow-up. At latest follow-up, medial proximal tibial angle deviation from normal was similar for the 2 groups; posterior proximal tibial angle was significantly greater in the AC group (5.6 degrees) than in the GC group (1.9 degrees). Mechanical axis deviation was significantly greater in the AC group (17.1 mm) than in the GC group (3.1 mm). Postoperatively, frequency of accurate translation corrections (achieved translation within 5 mm of preoperative required translation) was significantly greater in the GC group (18/18) than in the AC group (7/14). Frequency of accurate angulation corrections (medial proximal tibial angle within 3 degrees of normal and posterior proximal tibial angle within 5 degrees of normal) was significantly greater in the GC group (17/18) than in the AC group (7/14). For both groups, all tibiae with preoperative internal rotation deformity had accurate rotation correction. Correction of preoperative limb-length inequality was achieved in 5 of the 7 patients in the AC group and 11 of the 11 patients in the GC group. Gradual deformity correction is a more accurate treatment method of tibia vara than acute correction.

Key Words: tibia vara, Blount disease, external fixator

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Infantile[1,2] and adolescent tibia vara,[3,4] also known as infantile and adolescent Blount disease, respectively, are complex deformities for which corrective osteotomy[5] with the use of external fixation is a well-established treatment. The goals of surgery are to correct the deformity, restore the mechanical axis, and equalize limb lengths.

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Correction of tibia vara includes the correction of angulation, rotation, and length. Although aesthetic appearance and relief of pain may be the primary concern for the patients, the parents, and the surgeon, an objective assessment of the deformity correction must be conducted to identify residual and secondary deformities. Precise correction may be necessary to delay or prevent secondary osteoarthritis and disability in adulthood.[6–8]

Several studies have reported success in the acute treatment of the angular and rotational deformity of tibia vara with monolateral external fixation.[9–16] In addition, a number of authors[17–20] have demonstrated that gradual correction (GC) with the circular (Ilizarov technique) external fixator is an effective method in the treatment of tibia vara. No study has directly compared the clinical and radiographic outcomes in patients receiving acute correction (AC) with external fixation versus GC with circular external fixation for the treatment of tibia vara. The purpose of our study was to assess the accuracy of deformity correction achieved in patients with tibia vara using acute intraoperative correction as compared with using gradual postoperative correction.

METHODS

The clinical charts and serial radiographs of 47 consecutive patients who had correction of tibia vara between January 1995 and March 2000 were reviewed retrospectively. Institutional review board approval for the study was obtained. Thirty-two of the patients had complete radiographic data and were included in this study. The patients were divided into 2 groups, the AC group and the GC group.

The AC group consisted of 14 patients (14 tibiae), 8 male subjects and 6 female subjects, whose tibia vara was corrected acutely and held using an EBI external fixator (EBI Medical, Inc, Parsippany, NJ). The mean age was 11.4 years (range, 3–17 years). Four had infantile tibia vara, and 10 had adolescent tibia vara. Of the 4 patients with infantile tibia vara, 2 were classified as Langenskiöld stage III; 1 was classified as stage IV, and 1 was classified as stage V.[21–23] The EBI fixator construct consisted of multiple uniaxial joints connected together that permit multiplanar movement and rotation. This allowed for adjustment after the half pins were fixed to the bone. The small arc or a Garche T clamp was used for proximal metaphyseal fixation. The osteotomy was located below the tibial tubercle at the metaphyseal-diaphyseal junction. Acute correction was confirmed by fluoroscopy and Bovie cord technique. This aided in determining intraoperative correction of mechanical axis and joint alignment. Intraoperative prophylactic fasciotomy was performed on all the patients.

The GC group was composed of 18 patients (18 tibiae), 12 male subjects and 6 female subjects, whose tibia vara was corrected gradually using 6-axis deformity analysis and the Taylor Spatial Frame (Smith & Nephew, Inc, Memphis, TN). Three patients had bilateral corrections as staged procedures, but only the side that was treated first was included in the study. The mean age was 10.2 years (range, 3–16 years). Six had infantile tibia vara, and 12 had adolescent tibia vara. Of the 6 classified as infantile-type, 2 were Langenskiöld stage II, one was stage III, and 2 were stage IV. One tibia was Langenskiöld stage V and underwent a concurrent lateral proximal tibial hemiepiphysiodesis. The osteotomy was performed below the tibial tubercle. Fasciotomies were not performed on this group. Gradual deformity correction commenced 7 days after surgery. Patients and family were instructed in pin care and daily turns of the strut.

Preoperatively, patients in both groups had full-length standing anteroposterior (with knees in extension and patella directed anteriorly) and lateral radiographs of both limbs. The deformity was calculated on the anteroposterior and lateral tibial films using the methods described by Paley et al.[24] In addition, 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.

All patients underwent surgery under general anesthesia on the day of admission. Prophylactic perioperative antibiotics were administered to all the patients. A tourniquet was not used during the procedure for either group. The tibial osteotomy was performed with multiple drill holes and an osteotome. Patients in both groups were discharged, weight bearing as tolerated, with crutches or a walker.

Patients were followed by serial radiographs every 4 to 6 weeks beginning at 2 weeks postoperatively. External fixation was routinely maintained until 3 cortices osseous healing was evident on anteroposterior and lateral radiographs.

The anterior distal tibial angle (ADTA), mechanical lateral distal femoral angle (mLDFA), lateral distal tibial angle (LDTA), and posterior distal femoral angle (PDFA) were measured only preoperatively. The medial proximal tibial angle (MPTA), posterior proximal tibial angle (PPTA), and mechanical axis deviation (MAD) were measured preoperatively, postoperatively at the time of the removal of the external fixator, and at the latest follow-up 2 years after correction of the deformity. In addition, the postoperative and latest follow-up deformity corrections were recorded as accurate angulation corrections if the MPTA was within 3 degrees of normal (87 ± 3 degrees), and the PPTA was within 5 degrees of normal (80 ± 5 degrees).

Because the osteotomy was distal to the center of rotation of angulation for all of the tibiae, we calculated the required coronal and sagittal plane translations of the tibial shaft on the anteroposterior and lateral radiographs needed after the osteotomy to correct the MAD and joint orientation. The preoperative calculations were compared with the translations achieved postoperatively. In addition, the achieved translations were considered accurate translation corrections if both the coronal and the sagittal plane translations were within ±5 mm of their required translations.

Clinical assessment of rotation was conducted by examining the thigh-foot axis in the prone position preoperatively and at latest follow-up. Tibial rotation was recorded as accurate rotation correction if 0 to 15 degrees of external rotation was present at latest follow-up.

Limb lengths were measured on standing limb-length radiographs preoperatively and at latest follow-up. Accurate length correction was recorded if the limb-length inequality was 10 mm or less.

Statistical Analysis

For all radiographic measurements, the magnitude of the deformity for each variable (except translation) was determined by calculating the absolute value of the difference between the measured value and the normal value for that variable. For the preoperative required coronal and sagittal plane translations, the actual measurement values were used. Postoperatively, for the 2 translations, the absolute difference between the required and the achieved translations was used to determine the additional translation needed to attain alignment. However, in those cases of overcorrection, the absolute difference from zero equaled the additional translation needed.

The AC and GC groups were compared using *t* tests for independent samples on the following: (1) age, ADTA, mLDFA, LDTA, and PDFA only preoperatively, (2) MPTA, PPTA, and MAD preoperatively, postoperatively, and at follow-up, (3) the total time that the external fixator was used, (4) the required coronal and sagittal plane translations, and (5) the additional coronal and sagittal plane translations needed.

The Fisher exact test for 2 × 2 tables was used to compare the 2 groups on the following: (1) the frequency of the accurate angulation corrections postoperatively and at latest follow-up and (2) the frequency of accurate translation corrections postoperatively. For all analyses, a P value of less than 0.05 was considered statistically significant.

The frequency and magnitude of preoperative tibial internal rotation deformity, the frequency and magnitude of tibial external rotation at latest follow-up, and the frequency of accurate rotation corrections were determined for each group.

TABLE 1. Results of *t* Tests for Preoperative Variables

	AC Group (n = 14)			GC Group (n = 18)			
	Mean	SD	Range	Mean	SD	Range	*P*
Age, y	11.4	5.0	3–17	10.2	4.4	3–16	0.45
MPTA, degree	14.5	7.0	5–27	16.1	9.5	7–49	0.61
PPTA, degree	9.3	5.7	1–20	9.6	6.0	1–20	0.90
MAD, mm	64.6	20.4	34–102	54.9	22.0	31–120	0.21
ADTA, degree	5.7	3.4	1–12	6.0	3.2	0–10	0.81
mLDFA, degree	5.4	3.1	1–12	0.8	0.7	0–2	0.001
LDTA, degree	3.6	3.2	0–9	1.7	2.3	0–10	0.07
PDFA, degree	3.4	2.3	0–7	5.2	2.2	2–10	0.03

TABLE 2. Results of *t* Tests for MPTA, PPTA, and MAD Postoperatively and at Latest Follow-up

	AC Group (n = 14)			GC Group (n = 18)			
	Mean	SD	Range	Mean	SD	Range	P
MPTA, degree							
Postoperative	3.4	5.8	0–20	1.3	0.9	0–3	0.20
Follow-up	3.9	5.1	0–17	1.3	1.1	0–4	0.09
PPTA, degree							
Postoperative	5.1	4.2	0–12	1.4	1.2	0–4	0.007
Follow-up	5.6	5.7	0–18	1.9	1.4	0–5	0.03
MAD, mm							
Postoperative	13.9	11.0	2–40	1.5	1.4	0–4	0.001
Follow-up	17.1	12.9	0–40	3.1	3.4	0–15	0.001

The frequency and magnitude of preoperative and latest follow-up limb-length inequalities and the frequency of accurate length corrections were calculated.

RESULTS

Table 1 contains the results of the *t* tests for independent samples for age and the preoperative measurements of the magnitude of the deformity for each of the variables. Preoperatively, the mean age, MPTA, PPTA, MAD, ADTA, and LDTA were similar for the 2 groups. The mean mLDFA was significantly greater in the AC group than in the GC group (5.4 degrees versus 0.8 degrees), whereas the mean PDFA was significantly greater in the GC than in the AC group, 5.2 degrees versus 3.4 degrees.

The total time that the external fixator was used was similar for the 2 groups, with a mean of 12.9 weeks (range, 8–22 weeks) for the AC group and a mean of 14.3 weeks (range, 9–24 weeks) for the GC group.

The results of the *t* tests for independent samples for the magnitude of the deformity for MPTA, PPTA, and MAD postoperatively and at latest follow-up are reported in Table 2. For the PPTA, the postoperative AC group mean of 5.1 degrees was significantly greater than the GC group mean of 1.4 degrees. At latest follow-up, the AC group mean of 5.6 degrees was significantly greater than the GC group mean of 1.9 degrees. For the MAD, the postoperative AC group mean of 13.9 mm was significantly greater than the GC group mean of 1.5 mm. At latest follow-up, the AC group mean of 17.1 mm was significantly greater than the GC group mean of 3.1 mm.

TABLE 3. Results of Fisher Exact Test for Accurate Angulation Corrections

	AC Group (n = 14)	GC Group (n = 18)	
	n (%)	n (%)	P
Postoperative			
Accurate	8 (57.1)	18 (100)	0.003
Unsatisfactory	6 (42.9)	0	
Follow-up			
Accurate	7 (50.0)	17 (94.4)	0.010
Unsatisfactory	7 (50.0)	1 (5.6)	

TABLE 4. Results of *t* Tests for Coronal and Sagittal Plane Translations

Type of Translation	AC Group (n = 14)			GC Group (n = 18)			
	Mean	SD	Range	Mean	SD	Range	P
Coronal, mm							
Required	8.9	9.4	0–34	13.3	4.7	5–22	0.09
Additional	7.0	7.7	0–26	1.6	1.4	0–5	0.02
Sagittal, mm							
Required	6.2	6.2	0–17	9.4	3.9	0–17	0.08
Additional	3.0	2.9	0–9	2.0	1.3	0–5	0.25

The Fisher exact test demonstrated postoperatively a significantly greater frequency of accurate angulation corrections in the GC group (18 of 18 tibiae) than in the AC group (8 of 14 tibiae) (Table 3). Of the 6 unsatisfactory results in the AC group, 1 tibia had undercorrection of MPTA only (varus), 3 had undercorrection of PPTA only (procurvatum), and 2 had overcorrection of both MPTA and PPTA (valgus/recurvatum). At latest follow-up, a significantly greater frequency of accurate angulation corrections was found in the GC group (17 of 18) than in the AC group (7 of 14) (Table 3). In the AC group, 1 tibia had lost accurate correction of PPTA, and one had lost accurate correction of MPTA (in addition to previous unsatisfactory PPTA). In the GC group, 1 tibia had lost accurate correction of MPTA.

Table 4 contains the results of the *t* tests for independent samples for the required and the additional translations in the coronal and sagittal planes. The additional translation needed was significantly greater in the coronal plane for the AC group (7.0 mm) than for the GC group (1.6 mm). Postoperatively, the frequency of accurate translation corrections was significantly greater (Fisher exact test, $P = 0.001$) in the GC group (18 of 18 tibiae) than in the AC group (7 of 14 tibiae) (Table 5). In the AC group, 4 tibiae needed additional translation of greater than 5 mm in only the coronal plane, 1 tibia in only the sagittal plane, and 2 tibiae in both planes.

Preoperatively, 4 tibiae in the AC group had a mean internal rotation deformity of 16.2 degrees (range, 10–25 degrees). At latest follow-up, these 4 tibiae had a mean external tibial rotation of 7.4 degrees (range, 0–15 degrees of external rotation). Preoperatively, 6 tibiae in the GC group showed a mean internal rotation deformity of 14.4 degrees (range, 10–30 degrees). At latest follow-up, these 6 tibiae had a mean external tibial rotation of 6.5 degrees (range, 0–10 degrees of external rotation). For both groups at latest follow-up, all tibiae had accurate rotation correction.

TABLE 5. Results of Fisher Exact Test for Accurate Translation Corrections

	AC Group (n = 14)	GC Group (n = 18)	
	n (%)	n (%)	P
Accurate	7 (50)	18 (100)	0.001
Unsatisfactory	7 (50)	0	

Preoperatively, 7 patients in the AC group had limb-length inequality of greater than 10 mm, with a mean of 15.6 mm (range, 11–35 mm). At final follow-up, their mean limb-length inequality was 3.4 mm (range, −5–20 mm). Accurate length correction was achieved in 5 of these patients, but 2 had residual shortening of 15 and 20 mm. Preoperatively, 11 patients in the GC group had limb-length inequality of greater than 10 mm, with a mean of 17.2 mm (range, 11–30 mm). At latest follow-up, their mean limb-length inequality was reduced to 2.1 mm (range, −5–10 mm) and therefore, all of these patients had accurate length correction.

Complications included 2 pin-tract infections in the AC group and 3 in the GC group that resolved with antibiotics. One patient in the AC group had delayed union. No compartment syndromes or peroneal nerve palsies occurred in either group.

DISCUSSION

Corrective osteotomy for tibia vara may be performed with AC or GC. External fixation offers several advantages over internal fixation,[13–15] including the ability to modify the correction of limb alignment in the postoperative period and translate the osteotomy when required.

Acute correction with an external fixator continues to be seen as an attractive construct because it allows for dynamic compression, minimal postoperative adjustments, and early postoperative weight bearing. Several authors have reported their results using AC and an external fixator for the correction of infantile and adolescent tibia vara.[13–16,25] Price et al[15] reported a 20-degree mean correction of the mechanical axis, significant improvements in the tibiofemoral and metaphyseal-diaphyseal angles, and good results in 81% of tibiae (both infantile and adolescent tibia vara) treated with the Orthofix device (Orthofix, Verona, Italy). Of the 6 tibiae that had poor results, 4 had excessive residual varus at the latest follow-up. Deformity corrections in the sagittal plane were not described. Smith et al[16] achieved an average of 24.4 degrees of correction in mechanical axis varus at an average of 2.7 years of follow-up, yielding 15 excellent results in 23 extremities with adolescent tibia vara. These authors were unable to address the correction of tibial torsion because of incomplete preoperative measurements. Gaudinez and Adar,[13] whose series of 11 patients was limited to patients with adolescent tibia vara, achieved a mean correction of the tibiofemoral angle of 16 degrees, a mean correction of the metaphyseal-diaphyseal angle of 10.5 degrees, and an average mechanical axis improvement of 4 degrees. Because they did not measure the joint-line obliquity, one cannot be sure of the orientation of the joint lines.

Gradual deformity correction of tibia vara, using circular (Ilizarov technique) devices,[17–20,26,27] has been advocated to reduce the complications, including peroneal nerve palsy, compartment syndrome, residual deformity, limb-length inequality, delayed union, and failure of fixation, associated with acute corrective proximal tibial osteotomy.[15,23,28–33] Circular external fixators provide angular correction in multiple planes, allowing procurvatum, internal tibial torsion, and length inequality to be corrected concomitantly with the hallmark proximal tibial varus. The progressive correction afforded by distraction osteogenesis minimizes the surgical exposure required for the osteotomy[34] and may avoid deleterious traction on the regional neurovascular structures. Clinical studies[17–20,27] have reported the successful use of GC of the multiple deformity components of tibia vara.[35] In 25 tibiae with a preoperative mean tibial varus deformity of 27 degrees, Stanitski et al[20] achieved axial alignment within 5 degrees of normal or of the contralateral side using the Ilizarov technique, and all patients were rated as having good results according to the criteria of Schoenecker et al[36] and were pain-free. Coogan et al[17] corrected a preoperative mean varus malalignment of 26 degrees in the mechanical axis to a mean of 8 degrees and a mean tibial varus deformity of 18 degrees to a postoperative mean deviation of 2.5 degrees from normal anatomical alignment but inadequately reduced the average sagittal plane procurvatum deformity from 19 degrees to 9 degrees using Ilizarov fixation.

Our results demonstrated a more accurate angular correction in the GC group (100%) than in the AC group (57.1%). This was noted by the presence of residual varus, procurvatum, and valgus/recurvatum postoperatively in the AC group. The MAD correction was better in the GC group; however, this can be accounted for by the difference in the preoperative femoral deformities between the 2 groups.

Despite meticulous preoperative planning when performing AC with external fixators, one has to sequentially stage, at times requiring the return to the operating room, the angulation, rotation, translation, and lengthening of the bone. This may be difficult to control and prone to error.[27] There is limited scope to acutely correct the translation and then estimate the MAD. The Bovie cord method of estimating the MAD may yield erroneous results because one could have a normal mechanical axis with oblique joint lines by over-angulation instead of translation of the bone. However, with GC, we found that accurate correction of the deformity in 6 axes was achievable without recourse to complicated maneuvers like modifying the frame and anesthetizing the patient. In addition, the learning curve for the GC with the Taylor Spatial Frame did not seem large as it was described for the Ilizarov method.[27]

In conclusion, gradual deformity correction is a more accurate treatment for tibia vara than AC. Subsequent studies are necessary to determine if this conclusion holds true for all lower extremity deformities.

REFERENCES

1. Blount WP. Tibia vara, osteochondrosis deformans tibiae. *Curr Pract Orthop Surg*. 1966;3:141–156.
2. Blount WP. Tibia vara: osteochondrosis deformans tibiae. *J Bone Joint Surg Am*. 1937;19:1–29.
3. Beskin JL, Burke SW, Johnston CE II, et al. Clinical basis for a mechanical etiology in adolescent Blount's disease. *Orthopedics*. 1986;9:365–370.
4. Wenger DR, Mickelson M, Maynard JA. The evolution and histopathology of adolescent tibia vara. *J Pediatr Orthop*. 1984;4:78–88.
5. Bradway JK, Klassen RA, Peterson HA. Blount disease: a review of the English literature. *J Pediatr Orthop*. 1987;7:472–480.
6. Kettlekamp DB, Hillberry BM, Murrish DW, et al. Degenerative arthritis of the knee secondary to fracture malunion. *Clin Orthop*. 1988;234:159–169.

7. McKellop HA, Llinas A, Sarmiento A. Effects of tibial malalignment of the knee and ankle. *Orthop Clin North Am*. 1994;25:415–423.
8. Puno RM, Vaugh JJ, Stetten ML, et al. Long-term effects of tibial angular malunion on the knee and ankle joints. *J Orthop Trauma*. 1991;5:247–254.
9. de Pablos J, Alfaro J, Barios C. Treatment of adolescent Blount disease by asymmetric physeal distraction. *J Pediatr Orthop*. 1987;17:54–58.
10. de Pablos J, Fanzreb M. Treatment of adolescent tibia vara by asymmetrical physeal distraction. *J Bone Joint Surg Br*. 1993;75:592–596.
11. Fowler JL, Gie GA, MacEachern AG. Upper tibial valgus osteotomy using a dynamic external fixator. *J Bone Joint Surg Br*. 1991;73:690–691.
12. Ganel A, Heim M, Farine I. Asymmetric epiphyseal distraction in treatment of Blount's disease. *Orthop Rev*. 1986;15:237–240.
13. Gaudinez R, Adar U. Use of Orthofix T-Garche Fixator in late-onset tibia vara. *J Pediatr Orthop*. 1996;16:455–460.
14. Kamegaya M, Shinohara Y, Shinada Y. Limb lengthening and correction of angulation deformity: immediate correction by using a unilateral fixator. *J Pediatr Orthop*. 1996;16:477–479.
15. Price CT, Scott DS, Greenberg DA. Dynamic axial external fixation in the surgical treatment of tibia vara. *J Pediatr Orthop*. 1995;15:236–243.
16. Smith SL, Beckish ML, Winters SC, et al. Treatment of late-onset tibia vara using Afghan percutaneous osteotomy and Orthofix external fixation. *J Pediatr Orthop*. 2000;20:606–610.
17. Coogan PG, Fox JA, Fitch RD. Treatment of adolescent Blount disease with circular external fixation device and distraction osteogenesis. *J Pediatr Orthop*. 1996;16:450–454.
18. Miller S, Radomisli T, Ulin R. Inverted arcuate osteotomy and external fixation for adolescent tibia vara. *J Pediatr Orthop*. 2000;20:450–454.
19. Monticelli G, Spinelli R. A new method of treating the advanced stages of tibia vara (Blount's disease). *Ital J Orthop Traumatol*. 1984;10:295–303.
20. Stanitski DF, Dahl M, Louie K, et al. Management of late-onset tibia vara in the obese patient by using circular external fixation. *J Pediatr Orthop*. 1997;17:691–694.
21. Langenskiöld A, Riska EB. Tibia vara. *J Bone Joint Surg Am*. 1964;46:1405–1420.
22. Langenskiöld A. Tibia vara (osteochondrosis deformans tibiae). *Acta Chir Scand*. 1952;103:1–22.
23. Langenskiöld A. Tibia vara, osteochondrosis deformans tibiae. Blount's disease. *Clin Orthop*. 1981;158:77–82.
24. Paley D, Herzenberg JE, Tetsworth K, et al. Deformity planning for frontal and sagittal plane corrective osteotomies. *Orthop Clin North Am*. 1994;25:425–465.
25. De Bastiani G, Aldegheri R, Renzi-Brivio L, et al. Limb lengthening by callus distraction (callotasis). *J Pediatr Orthop*. 1987;7:129–134.
26. Feldman DS, Madan SS, Koval KJ, et al. Correction of tibia vara with six-axis deformity analysis and the Taylor spatial frame. *J Pediatr Orthop*. 2003;23:387–391.
27. Tetsworth KD, Paley D. Accuracy of correction of complex lower-extremity deformities by the Ilizarov method. *Clin Orthop*. 1994;301:102–110.
28. Henderson RC, Kemp GJ, Greene WB. Adolescent tibia vara: alternatives for operative treatment. *J Bone Joint Surg Am*. 1992;74:342–350.
29. LaMont RL, Prasad B. Experience with dome shaped osteotomy of the upper tibia for multiplane correction. *Clin Orthop*. 1973;91:152–157.
30. Matsen FA, Staheli LT. Neurovascular complications following tibial osteotomy in children. A case report. *Clin Orthop*. 1975;110:210–214.
31. Pinkowski JL, Weiner DS. Complications in proximal tibial osteotomies in children with presentation of technique. *J Pediatr Orthop*. 1995;15:307–312.
32. Steel HH, Sandrow RE, Sullivan PH. Complications of tibial osteotomy in children for genu varum or valgum. *J Bone Joint Surg Am*. 1971;53:1629–1635.
33. Thompson GH, Carter JR, Smith CW. Late onset tibia vara: a comparative analysis. *J Pediatr Orthop*. 1984;4:185–194.
34. Paley D, Tetsworth K. Percutaneous osteotomies: osteotome and Gigli saw techniques. *Orthop Clin North Am*. 1991;22:613–624.
35. Bell DF. Treatment of adolescent Blount's disease using the Ilizarov technique. *Oper Tech Orthop*. 1991;2:149–155.
36. Schoenecker PL, Meade WC, Pierron RL, et al. Blount's disease: a retrospective review and recommendations for treatment. *J Pediatr Orthop*. 1985;5:181–186.

