New Single-stage Double Osteotomy for Late-presenting Infantile Tibia Vara: A Comprehensive Approach

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Background: Successful surgical treatment of late-presenting infantile tibia vara (ITV) patient requires the correction of oblique deformities. The purpose of this study was to report on a new comprehensive approach to correct and prevent recurrence of these deformities with a single procedure.

Methods: Medical records of 23 consecutive children (7 to 18 y) with advanced ITV (29 knees) were retrospectively reviewed after a mean of 7.3 years postoperatively (range, 2 to 22 y). Indications for the corrective surgery were any child 7 year or older with a varus mechanical axis angle ≥ 10 degrees or a varus anatomic axis angle ≥ 11 degrees and a medial tibial angle (MTA) slope < 60 degrees. The deformities were corrected with a dome-shaped osteotomy proximal to the tibial tubercle with a midline vertical extension to the subchondral region of the joint and a lateral hemi-epiphysiodesis.

Results: At latest follow-up, means and medians of each tibial radiographic axis measurement improved significantly from preoperative values ($P < 0.001$): mechanical axis angle from 23 degrees to 4 degrees varus, anatomic axis angle from 25 degrees varus to 1 degree valgus, MTA downward slope from 30 to 78 degrees, posterior MTA from 59 to 80 degrees. In total, 79% and 74% had good to excellent results based on radiographic criteria and clinical questionnaire for satisfaction, pain and function, respectively. Two abnormal medial tibial plateau types were described.

Conclusions: This is the first study to use a single-stage double osteotomy performed proximal to the tibial tubercle for the late-presenting ITV for children 7 years of age or older. In addition to the effective correction of the 4 major tibial deformities, a lateral proximal tibial hemi-epiphysiodesis minimizes recurrence of tibia vara. A contralateral proximal tibial epiphysiodesis is recommended for treated skeletally immature patients with unilateral disease.

Level of Evidence: Therapeutic level IV. See instructions for authors for a complete description of levels of evidence.

Key Words: tibial dome osteotomy, infantile tibia vara, Blount disease

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Early untreated infantile tibia vara (ITV) as seen in the toddler is characterized clinically by progressive bowing of the leg and internal tibial torsion. Serial radiographs of the proximal tibia show the typical epiphyseal, growth plate, and metaphyseal changes: loss of height of the medial tibial epiphysis, increase of the downward sloping, and irregularity of medial growth plate and tibia vara.

The ideal time to reverse these changes is to brace the leg or perform a valgus tibial osteotomy before the age of 3 and 4 years, respectively.[1–6] However, if the disorder progresses to Langenskiöld Stage IV to VI or if there are significant residual deformities after treatment, a comprehensive surgical plan is required to correct the deformities in multiple planes.

There are several reports of single procedures reported to correct these deformities: valgus metaphyseal osteotomy,[7,8] medial tibial plateau elevation,[9–11] and medial epiphysiolysis of the growth plate.[12] Others have combined these procedures in 1 or 2 stages.[13–18] Recurrence of varus and persistence of abnormal medial articular slope of tibia may be due in part to failure to arrest a growing lateral growth plate or to correct the procurvatum.[19,20] Additional reporting on treatment outcomes with longer follow-up are needed before a modern consensus for treatment can be widely adopted.

We hypothesize that all the significant tibial deformities associated with late-presenting ITV can be treated successfully in most instances with a single procedure based on a double tibial osteotomy done proximal to the tibial tubercle. It is the aim of this retrospective cohort study to report on a new comprehensive surgical approach to treat late-presenting ITV with a single-stage double tibial osteotomy designed to correct the deformities and prevent recurrence.

TABLE 1. Summary of Patient Preoperative Radiographic Data and Most Recent Follow-up Postoperative Data and Results

						Anatomic Axis*		Mechanical Axis†		MTA‡
Patient (sex)	Location	Side	Langenskiöld	Age at Surgery (y)	Follow-up (y)	Preop	Postop	Preop	Postop	Preop
1 (F)	1	R	VI	18.1	22.2	−42	0	−30	−5	30
2 (F)¶	1	L	VI	10.5	19.9	−20	0	−17	−4	53
3 (F)	1	R	VI	9.6	15.6	−21	3	−17	0	35
4 (F)	1	R	VI	8.8	10.8	−28	8	−22	−3	32
5 (F)	1	R	V	7.2	9.1	−41	−1	−36	−1	33
	1	L	VI	8.7	7.9	−49	4	−42	−5	34
6 (F)	1	R	VI	8.7	8.0	−20	0	−16	1	35
	1	L	VI	10.8	6.0	−16	0	−12	−2	56
7 (F)	1	R	V	8.6	7.6	−19	1	−25	−3	30
8 (F)	1	L	VI	8.3	6.9	−14	4	−12	−2	26
	1	R	VI	8.6	6.3	−15	6	−11	−2	22
9 (F)	1	L	VI	9.3	6.2	−24	−11	−21	−16	26
10 (F)¶	1	L	V	12.2	4.9	−30	−2	−24	−5	48
11 (F)	1	L	V	11.3	4.0	−27	5	−21	0	59
12 (F)	1	L	VI	13	3.0	−29	9	−31	2	59
	1	R	VI	13	2.0	−24	−9	−25	−15	48
13 (M)¶	1	L	VI	10.4	2.0	−23	−2	−16	−5	30
14 (F)¶	2	R	VI	9.4	10.0	−25	−2	−32	−10	13
15 (M)¶	2	L	VI	10.4	9.1	−32	4	NA	−5	33
16 (F)¶	2	L	V	8.2	9.0	−18	0	NA	5	54
17 (F)	2	L	VI	12.7	8.4	−32	2	NA	−3	27
18 (F)	2	L	VI	11.3	5.2	−37	4	NA	−1	53
19 (F)	2	R	VI	7.7	5.2	−12	8	NA	0	50
	2	L	VI	7.7	5.2	−12	6	NA	1	25
20 (F)	2	R	VI	6.7	4.2	−40	7	NA	−1	35
	2	L	VI	6.7	4.2	−32	−10	NA	−16	50
21 (M)¶	2	R	V	8.1	3.5	−29	0	NA	−5	45
22 (F)	2	L	VI	11.7	2.6	−16	−6	NA	−12	39
23 (M)	2	L	V	9.7	2.0	−11	6	NA	0	52
Mean				9.91	7.3	−25.4	1.2	−22.8	−3.9	39.0
Median				9.4	6.2	−24.0	1.0	−21.5	−3.0	35.0

All axis and angle measurements are given in degrees.
*Mechanical axis (normal ≤11).
†Anatomic axis (normal ≤ ± 5).
‡MTA (normal = 87 ± 2).
§PMTA (normal = 80 ± 3).
‖ALFA (normal = 81 ± 2).
¶Unilateral cases.
ALFA indicates anatomic lateral femoral angle; F, female; L, left; M, male; MTA, medial tibial angle; NA, not available or did not complete survey; PMTA, posterior medial tibial angle; Preop, preoperative; Postop, postoperative; R, right.

METHODS

Approval for this retrospective cohort study was granted by the Institutional Review Board. Medical records and radiographs of patients with late-presenting ITV were reviewed from 2 sites. Between January 1993 and June 2015, 26 patients with 33 limbs underwent the double osteotomy procedure. The inclusion criteria required each patient to be diagnosed originally with ITV. Indications for the corrective surgery were any child 7 year or older with a varus mechanical axis angle (MAA) ≥ 10 degrees or a varus anatomic axis angle (AAA) ≥ 11 degrees and a medial tibial angle (MTA) slope < 60 degrees. The minimal postoperative follow-up was 2 years. Two current patients with < 2 years of follow-up were excluded and a third was lost to follow-up. A total of 23 patients with 29 limbs remained eligible for study. During the 22-year study period, no other type of tibial osteotomy was performed for late-presenting ITV by the principal investigator.

Sixteen patients had bilateral ITV and 7 patients had unilateral disease. In some bilateral cases, the procedure studied was only performed on 1 limb. All 7 bilateral operated limbs and 13 unilateral cases were females. The average age at surgery was 9.9 years (7 to 18 y). Patients were followed for a mean length of 7.3 years (2 to 22 y) (Table 1). Previous to this procedure, 19 of 29 limbs (80%) had prior high tibial osteotomies and 21 patients were of African descent.

The preoperative and most recent standing radiographic studies were used to measure correction of deformities and to assess severity with the Langenskiöld staging system.[21] A least 2 of the authors measured the 5 radiographic angles used in this study. Each angle was measured 3 times by each examiner and an average angle

TABLE 1. (*continued*)

					Knee Range of Motion					
MTA‡	PMTA§		ALFA‖			Preoperative		Follow-up		
Postop	Preop	Postop	Preop	Postop	Radiographic	Extension	Flexion	Extension	Flexion	Questionnaire Outcome
75	30	65	80	86	Good	0	120	−10	145	Fair
83	47	90	84	86	Good	0	130	0	120	Good
90	85	89	90	90	Good	0	130	0	120	Good
63	77	78	81	80	Excellent	−10	130	0	120	Good
88	34	77	85	81	Good	−10	100	0	100	Poor
70	34	75	83	82	Excellent	−10	100	0	100	
75	47	87	82	86	Good	0	135	0	140	Good
88	52	78	81	84	Good	0	135	0	140	
75	73	65	90	86	Good	0	140	0	150	NA
71	35	85	81	81	Excellent	0	125	−3	125	NA
65	33	89	82	82	Excellent	0	140	−3	130	
83	42	80	84	90	Fair	0	125	−3	125	NA
80	51	80	83	86	Excellent	0	140	0	145	Good
90	74	79	82	84	Excellent	0	140	0	140	Good
90	40	86	83	82	Excellent	−5	125	0	120	Fair
90	50	68	85	85	Poor	−5	125	0	120	
82	74	84	84	83	Good	0	130	0	130	NA
61	61	90	90	85	Poor	0	130	−3	125	Fair
76	64	82	87	89	Excellent	0	130	0	95	Excellent
66	78	90	85	83	Fair	0	140	0	140	Good
66	80	70	85	86	Excellent	0	115	0	130	Good
90	90	88	83	83	Good	0	125	0	105	Good
67	50	90	85	88	Good	0	125	−10	130	Good
76	58	75	80	82	Excellent	0	120	0	120	
89	75	86	81	83	Excellent	−5	110	−10	130	Fair
90	80	84	80	80	Fair	0	95	0	120	
80	78	76	90	90	Good	−5	145	−5	135	Excellent
73	43	62	90	71	Poor	−15	145	−15	145	Good
74	69	82	84	87	Excellent	0	150	0	150	Excellent
78.1	58.8	80.3	84.1	84.2		−2.2	127.6	−2.1	127	
76.0	58.0	82.0	84.0	84.0		0	130	0	130	

was chosen for the use in the paper. Figure 1 shows the 5 angles measured: MAA (A), AAA (B), MTA (C), posterior MTA (PMTA) (D), and anatomic lateral femoral angle (E).[22] The preoperative MAA were not recorded for 11 of the 12 knees as these studies were not available. Complete correction of the 4 tibial and 1 femoral deformities were defined as a final MAA 0 ± 5 degrees, AAA = 6 ± 5 degrees, MTA = 87 ± 4 degrees, PMTA or procurvatum = 80 ± 6 degrees, and lateral femoral angle (LFA) = 81 ± 4.[13,23–25] For MTA, PMTA, and LFA an acceptable result was defined as falling within 2 SDs of the mean normal adult knee.

A 12-item scale questionnaire was developed and administered postoperatively by phone or during clinic visits (see supplementary appendix Table 1, Supplemental Digital Content 1, http://links.lww.com/BPO/A95). The survey was determined to be internally consisted by the Cronbach alpha method: $\alpha = 0.80$ for the satisfaction and $\alpha = 0.71$ for the pain symptoms and functioning measures.[26,27] Nineteen of 23 patients (83%) responded to the questionnaire.

The value of each weighted response to the questionnaire is listed in supplementary appendix Table 1 (Supplemental Digital Content 1, http://links.lww.com/BPO/A95). The total score for each patient was graded on a 93-point scale and recorded as a percentage. The patients were divided into 4 groups: excellent, good, and fair scores were divided into groups of 16 percentage points so that an excellent score was > 84%, good > 68%, and fair > 52%, respectively. A poor score was < 52%. This scale was chosen based upon our clinical data and the absence of any patient-reported outcome scale for pediatric patients with limb deformity.

The radiographic results were determined from the 4 measured parameters which calculated 1 of the 3 deformities of the leg: varus at the knee, downward medial slope, and posterior slope of the medial tibial plateau. Preoperatively, a small number of tibias had normal posterior slope for which correction credit was granted in each case. Again, the patients were grouped into 4 groups: excellent if 3 of the 4 radiographic measurements were

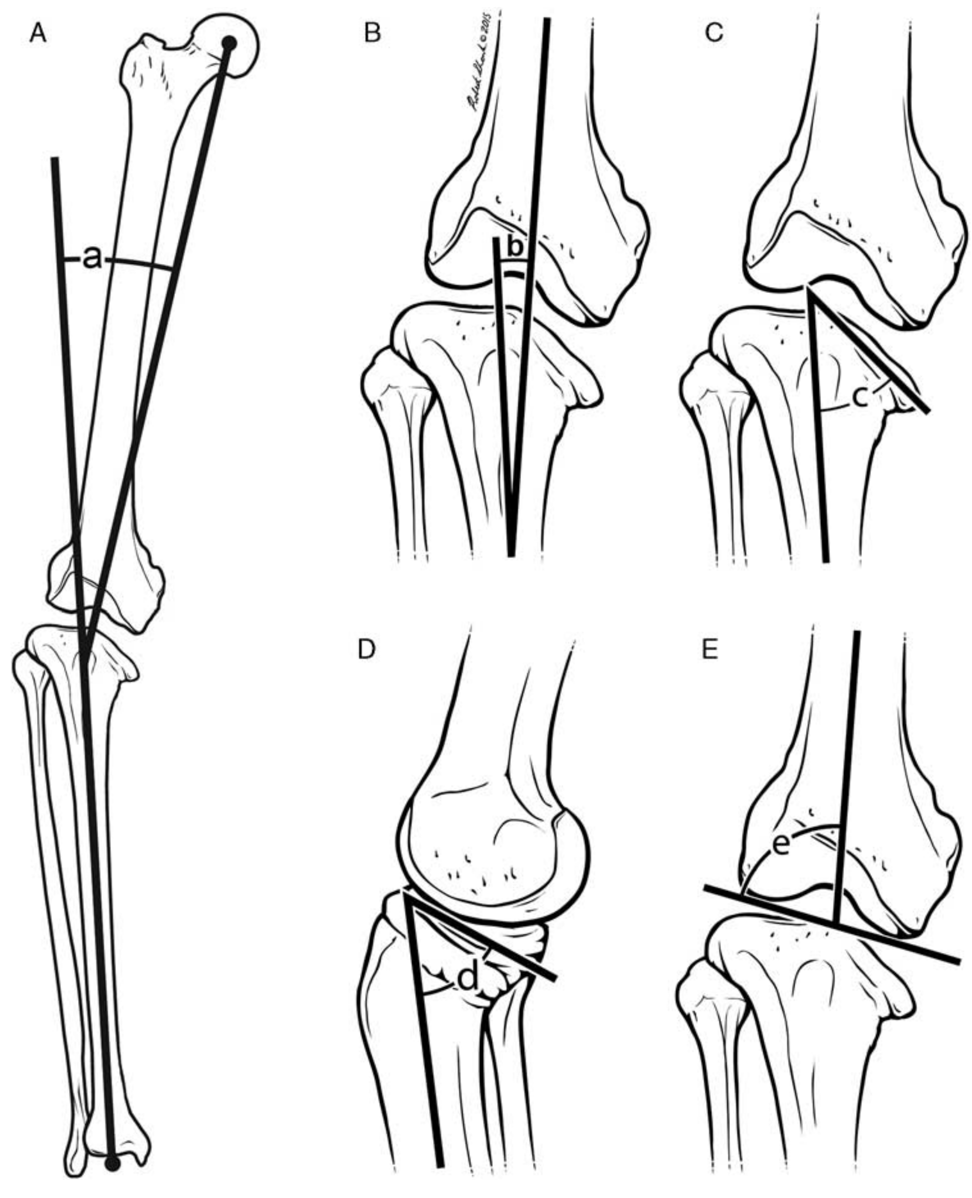

FIGURE 1. A–E, The 5 lower limb bony angles measured on anteroposterior and lateral radiographs. A, Mechanical axis angle formed by intersection of the femoral and tibial mechanical axes. B, Anatomic axis angle formed by the intersection of the femoral and tibial anatomic axes (C) medial tibial angle (MTA) formed by the tibial mechanical axis and the slope of medial tibial plateau. D, Posterior MTA created by the tibial anatomic axis and slope of the medial tibial plateau on a lateral film. E, Anatomic lateral femoral angle which is the lateral angle formed by the intersection of femoral anatomic axis and a line draw through the femoral condyle.

corrected, good if either MAA or AAA and one other parameter was corrected, fair if 1 abnormal parameter was corrected, and poor if none of the abnormal measurements were corrected.

Operative Techniques

The main operative steps are illustrated in Figure 2. An oblique fibula osteotomy was performed. The proximal tibia was approached by a 14-cm midline straight skin incision from the midpatellar ligament, and down the anterior surface of the tibia (Fig. 2A). Strategically placed Chandler retractors protected the posterior neurovascular structures in the popliteal fossa. A subperiosteal dome osteotomy was outlined by multiple 3.2 mm holes 3 cm distal to the joint and centered about the tibial tubercle and extending out to the medial and lateral cortices. The drill bit was angled distally and parallel to the joint subchondral bone on the sagittal plane (Fig. 2B). A lateral fluoroscopic radiograph was used to confirm the correct position of the drill bit. A 6-mm straight osteotome was used to connect the drill holes (Fig. 2C).

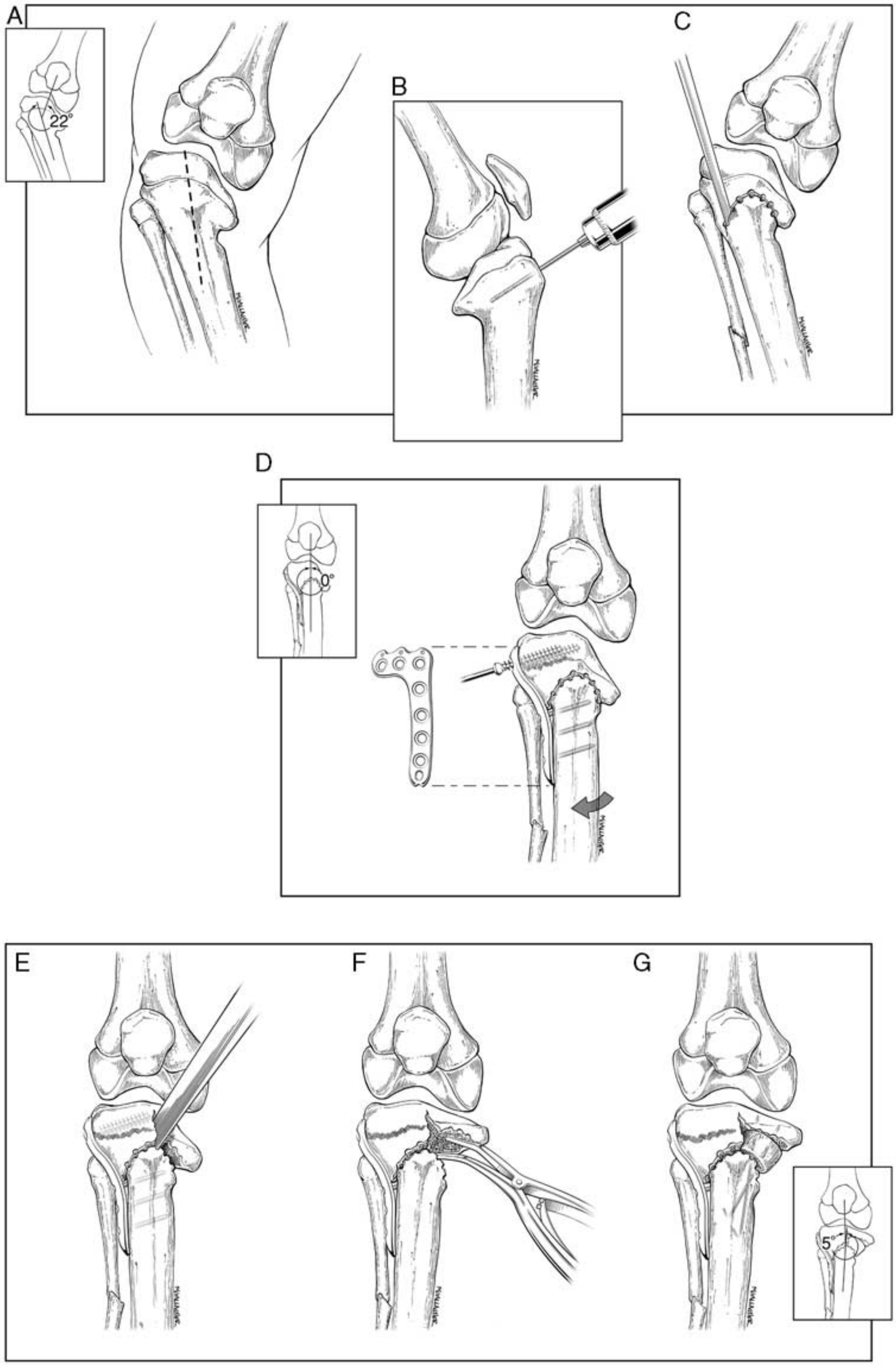

FIGURE 2. A–G, Double tibial and fibular osteotomies surgical steps. A, Skin incision (insert shows 22° varus deformity). B, Drill bit is placed at apex of planned dome osteotomy and parallel to joint surface. C, Dome osteotomy is outlined by drill holes and completed by osteotome. D, Lateral tibial plateau plate is applied with leg in corrected position and proximal to the growth plate (insert shows preoperative varus correction to 0°). E, Vertical osteotomy is performed from the apex of the dome osteotomy to subchondral bone. F, Spinal laminar spreader is used to fully elevate the medial tibial plateau and corrects the posterior procurvatum. G, Elevated medial tibial plateau is supposed with bone graft-materials and stabilized with Kirschner wire(s) (insert shows preoperative varus corrected to 5° valgus).

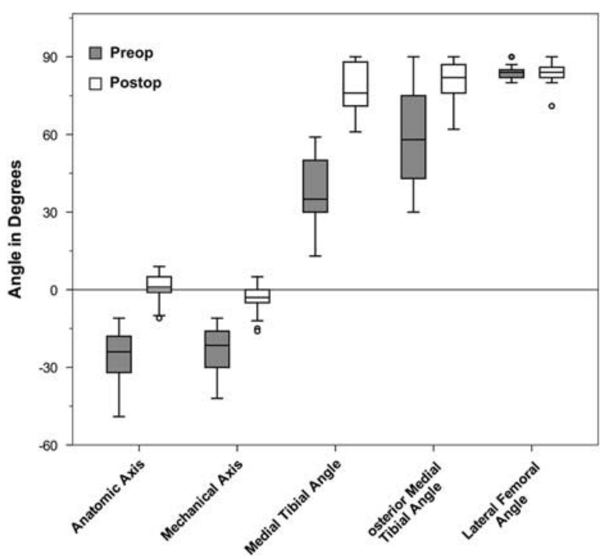

FIGURE 3. Box and whisker plot used to show the preoperative (preop) and postoperative (postop) radiographic measurements. The median value is represented by the line within the vertical box. The box spans from the 25th to the 75th percentile. Minor and extreme outliers are denoted by circles, respectively. Negative values indicate varus. Note with the exception of the lateral femoral angle results there was significant correction radiographically of the remaining deformities ($P<0.001$).

The lower leg was extended fully and externally rotated to 10 degrees or to the same degree as the normal contralateral leg. The genu varus deformity was corrected to neutral or 5 degrees valgus. An electrocautery cord placed over the femoral head, knee, and to the mid ankle joint confirmed the desired mechanical axis alignment with fluoroscopy. A 6-hole lateral tibial plateau plate was applied with the leg in the desired alignment (Fig. 2D). The lateral hemi-epiphysiodesis is accomplished by placing the proximal screws on the epiphyseal side of the growth plate and then advancing them to the midline of the tibia so as not to interfere with the second vertical osteotomy.

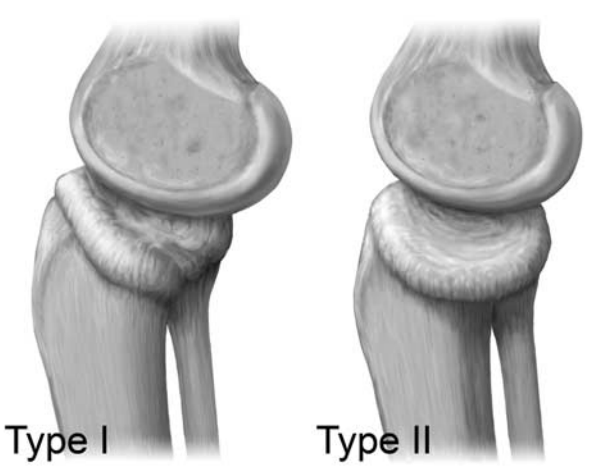

FIGURE 4. Type I and type II deformity patterns of the medial tibial plateau were seen. Type I, both medial and posterior slopes were present. Type II, only the medial tibial slope inclination was noted. Increased central depression of the medial tibial plateau was seen radiographically in both types.

The second osteotomy was performed with fluoroscopic guidance. An osteotome was placed anteriorly at the apex of the dome just medial to the proximal screw tips and extending proximal through the growth plate (Fig. 2E). It was hammered into the bone vertically and parallel to the joint's subchondral bone. The posterior cortex was osteotomized completely. A deeply placed spinal laminar spreader was used to completely hinge open the medial tibial plateau to correct its medial and posterior distal slopes (Fig. 2F). The maximally elevated plateau was supported by 1 or 2 full thickness diaphyseal fibula allografts, cut to fit the space. Iliac crest autograft is an alternative option. The impacted graft(s) was immobilized with 1 or 2 retrogradely placed Kirschner wire(s). At the end of the procedure, replacing a proximal screw(s) with longer one(s) may be considered provided that the graft complex is not disrupted.

A hemovac drain was placed. The periosteum was repaired. The tibialis anterior muscle was loosely and partially approximated over the drain and the wound was closed. Long-leg casts were applied for up to 4 months and discontinued if monthly radiographs determined evidence of bony union at both osteotomy sites. At that time, the patient was advanced from touchdown weight-bearing to full weight-bearing.

Statistical Analysis

The data for this study were imported into the SPSS software package, version 23 (Armonk, NY) for analysis. It was determined the radiographic parameters followed a nonparametric distribution. As a result, the medians are reported with the means, due to their robustness against outlier influence. For significance testing, the nonparametric Wilcoxon signed-rank test measured paired data. In all cases, statistical significance was set at the 0.05 level. The box-and-whisker-plot used in Figure 3 follows standard conventions.

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RESULTS

Radiographic Outcomes

The results of the radiographic data which include mean and median are shown in Table 1 and Figure 3. The procedure improved each of the 4 tibial radiographic angles on a significance level <0.001. The preoperative and follow-up LFA of the femur did not change significantly.

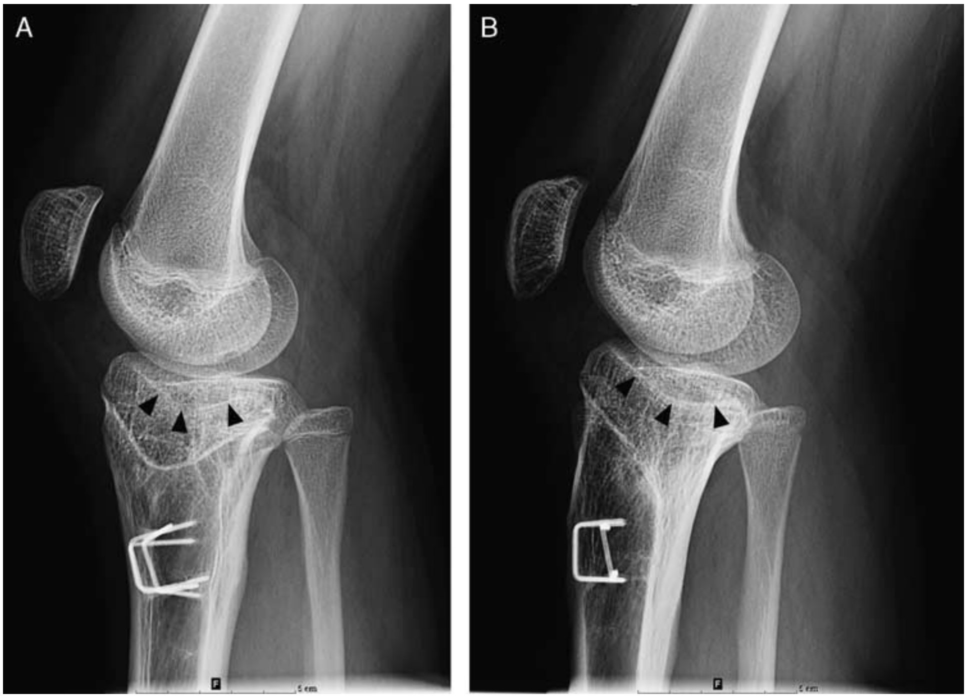

FIGURE 5. Case 6, A–B, Lateral views of right (A) and left (B) knees 5 years postoperatively. Note the increased depression of the central portion of the medial tibial plateau (black arrow heads).

Overall radiographic outcomes were good or excellent in 23 of 29 knees (79%), 3 were fair and 3 were poor. Of the 7 unilateral knees, 5 had good or excellent outcomes, 1 had a fair result, and 1 a poor result. Of the bilateral 22 knees, 18 had good or excellent results, 2 had fair, and 2 had poor outcomes.

At most recent follow-up, the MAA was within the range of -5 to 5 degrees in 24 of 29 (83%) knees. The AAA was within the range of 11 to 1 degrees in 15 of 29 (52%) knees. In addition, the postoperative MTA and PMTA angles were within the normal adult range in 11 of 29 (38%) and 16 of 29 (55%) knees, respectively. Achieving the normal adult values for these 5 parameters were the goals we hoped to achieve in the study. Because of the complex and chronic nature of the multiple deformities in each patient it was not possible to achieve normal adult values in all cases of the deformities particularly the severe cases.

Two types of medial tibial plateau deformities were identified (Fig. 4). In type 1 knees (n = 19, 66%), the PMTA was >2 SDs of normal (80 ± 3 degrees) or a procurvatum slope >16 degrees. In type II knees (n = 10, 34%), the PMTA was within 2 SDs or <16 degrees. Medial downward slope and central depression of the medial tibial plateau were present in both types. Increased central depression and persistent abnormal procurvatum of the medial tibial plateau may be important contributory factors for the premature development of knee osteoarthritis in these patients (Fig. 5).

TABLE 2. Summary of the Patient-reported Clinical Outcomes Subdivided by Bilateral and Unilateral Disease and Summary of Patients' Reported Outcome by Satisfaction, Pain, and Function

Outcomes	All Patients	Bilateral Disease	Unilateral Disease
Excellent	3	1	2
Good	11	8	3
Fair	4	3	1
Poor	1	1	0
Total	19	13	6
	Satisfaction	**Pain**	**Function**
Excellent	9	9	5
Good	6	3	11
Fair	4	1	1
Poor	0	6	2

Questionnaire Outcomes

The questionnaire outcome results of the 19 patients studied can be found in Table 2. Eighteen were overall satisfied with the surgery. Patients with bilateral ITV did not have a lower limb discrepancy >1 cm regardless of treatment on either tibia (Fig. 6). For the 7 unilateral ITV cases the average shortening of the operative leg was 24 mm (8 to 35 mm) at follow-up. Two of these patients underwent contralateral proximal tibial epiphysiodesis (Fig. 7).

The mean body mass index at follow-up was 36 (range, 19 to 70). At follow-up knees achieved a mean of 127 degrees of flexion (range, 95 to 150 degrees. Three of 4 knees with 10 degrees of flexion contracture preoperatively gained full extension at follow-up. And 3 of 4

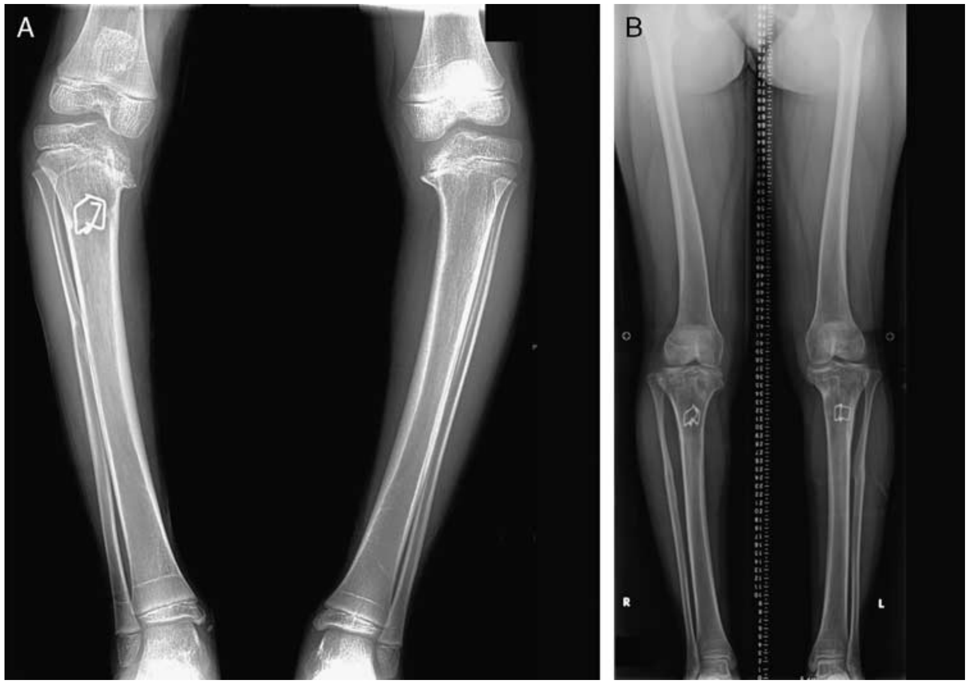

FIGURE 6. Case 6 patient with bilateral infantile tibia vara preoperative radiographs (A) and bilateral correction of mechanical axes measured within 1 degree of 0 (B). Limb-length discrepancy was <1 cm.

knees developed knee contractures of 10 to 15 degrees postoperatively. The remaining 25 knees were able to fully extend to 0 degree. Increased obesity contributed to those patients with decrease knee flexion.

Increased internal tibial torsion which was present in each patient preoperatively was corrected to ∼10 degrees of external rotation at the time of surgery. We were unable to accurately measure the patients' thigh-foot

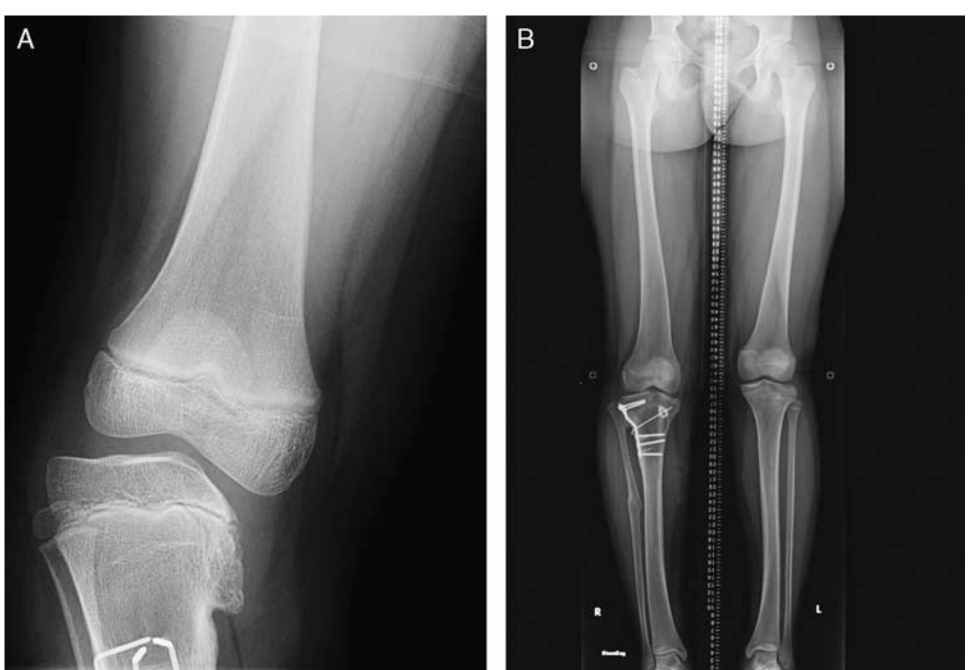

FIGURE 7. Case 7, unilateral case, (A) preoperative anterior posterior radiograph right tibia. (B) postoperative MAA radiograph 5 years after contralateral epiphyseodesis of proximal tibial growth plate. The MAA corrected to 0 degrees and the limb length discrepancy is reduced to 8 mm.

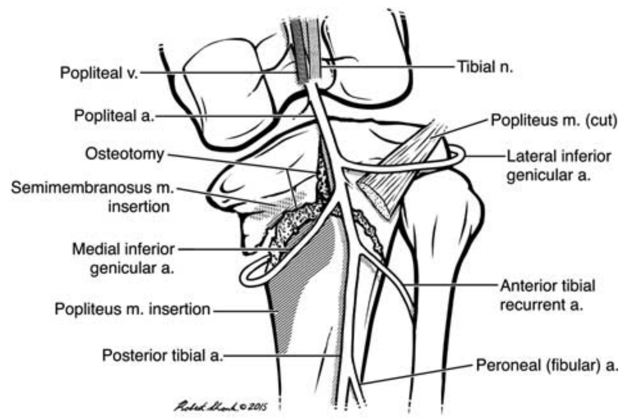

FIGURE 8. Anatomic illustration of the posterior view of the double osteotomy that relates to the arterial vessels in and about the popliteal fossa. The deeper popliteus muscle belly offers some protection to the vessels. a indicates artery; m, muscle; n, nerve; v, vein.

angle without formal gait analysis studies; however, in the clinical setting foot progression angle appeared to improve to within 20 degrees of internal or external rotation in all cases.

There were no cases of avascular necrosis, nonunion, or compartment syndrome in our patients. There was 1 superficial infection, a deep infection, and a wound dehiscence. There was also a transient and a permanent partial common peroneal nerve paresis. The latter occurred in case 26, who had a body mass index of 42, type I diabetes, and preoperatively had an anatomic axis of 32 degrees of varus.

DISCUSSION

The oblique deformity seen in late-presenting ITV treated with a single-stage double tibial osteotomy performed proximal to the tibial tubercle gave good to excellent radiographic results in 23 of 29 knees (79%). Also, the 19 clinical outcomes questionnaires reported good to excellent outcomes in 14 of 19 patients. Those results compare most favorably to other comparable recent studies.[18,28]

We attribute the 3 poor and 3 fair radiographic results to undercorrection of the varus deformity. This was primarily due to failure to correct the varus with the dome part of the osteotomy to 0 to 5 degrees valgus as a proximal lateral tibial hemi-epiphysiodesis is performed. The vertical osteotomy which is used to elevate the medial tibial plateau is not expected to add > 5 degrees of additional valgus correction because of the presence of the medial meniscus and unossified tibial plateau.[20]

Limb length is preserved as no significant bone is removed to correct the varus and internal torsion. As the osteotomy is performed at the level of the apex of the tibial deformity only axial correction without translocation is necessary to correct the varus.[29] It is important for anyone attempting this procedure to feel comfortable at performing the posterior tibial corticotomies as described. The popliteal and medial inferior geniculate arteries are in the immediate vicinity of the posterior corticotomies and are partially protected by the muscle belly of the popliteus muscle (Fig. 8).

An in-depth research of the ITV literature failed to cite any studies using external fixators with > 9 patients and or with a mean follow-up > 29 months.[8,11,13] In 1 study 6 cases treated with the Taylor Spatial Frame were followed on an average of 29 months.[8] They reported good results in all cases with the use of Schoenecker criteria. Also another study of 7 patients with an average follow-up of 29 months reported on their use of the Ilizarov Frame.[13] All their patients were improved and they were pleased with the results. We believe that these external fixator devices are better suited for the adolescent tibia vara where depression of the medial tibial plateau is less severe and where its elevation of the medial tibial plateau is required.

Others have attempted to rate the surgical outcome of treatment of the complex oblique deformity.[13,18,28] Although none have used all 4 of the major radiographic parameters and thus we feel their ratings are incomplete. The same can be said for assessing clinical outcomes on levels of pain. We sought to expand on previous attempts with a more comprehensive method involving 4 radiographic measures and a clinical outcome instrument to better evaluate and standardize results.

On the basis of the data collected and tabulated (Table 1) no patient had a MAA or AAA < 11 degrees. This does not mean that the same patient had a MAA equal to an AAA. In reviewing the literature for patients with ITV, either the AAA[13,18] or MAA[28] is used to calculate results. Here we used both measurements so as to compare our data with these publications. As the measurements of the AAA is readily available in all radiology facilities, it can be used in defining our indication criteria. In contrast, the MAA which may not be readily available in some radiology departments is a more accurate measurement of the lower limb alignment in the frontal plane. The addition of 6 degrees to the AAA to create a MAA was not always reproducible in our patient population. And this we believe is mainly due to the difficulty in defining the correct anatomic line of the femur and tibia which may present with varying degrees of varus and rotation for a given patient. These anatomic lines can also be affected by a knee subluxation. We found that the MAA which bypasses these issues to be easier and more reliable to measure than the AAA.

There are several limitations to the study. First, the techniques used to take the radiographs might not always have been standardized. Also, the actual measurements of the radiographic angles were subjected to individual bias. Second, the severity and chronicity of the oblique deformity of the medial tibial plateau made the comparison of some radiographic measurements to the normal stringent adult values difficult to achieve with the exception of the MAA and to a lesser extent the AAA. Third, a relatively small patient population may lead to inaccurate conclusions. This concern was off-set by high patient participation, the same principal medical team, and a moderately long period of follow-up. This study's size compares most favorably to other studies mentioned.

In conclusion, to our knowledge, this is the first study to present the technique and outcome of a single-stage double tibial osteotomy performed proximal to the tibial tubercle for late-presenting ITV for children 7 years or older. This comprehensive operation effectively corrects, in most cases, the 4 known deformities of tibial vara. A contralateral proximal tibial epiphysiodesis is recommended in the skeletally immature patient with unilateral disease. On the basis of our outcomes, we are comfortable in recommending this technique for ITV patients.

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REFERENCES

1. Ferriter P, Shapiro F. Infantile tibia vara: factors affecting outcome following proximal tibial osteotomy. *J Pediatr Orthop*. 1987;7:1–7.
2. Loder RT, Johnston CE. Infantile tibia vara. *J Pediatr Orthop*. 1987;7:639–646.
3. Greene WB. Infantile tibia vara. *J Bone Joint Surg Am*. 1993;75: 130–143.
4. Zionts LE, Shean CJ. Brace treatment of early infantile tibia vara. *J Pediatr Orthop*. 1998;18:102–109.
5. Richards BS, Katz DE, Sims JB. Effectiveness of brace treatment in early infantile Blount's disease. *J Pediatr Orthop*. 1998;18:374–380.
6. Raney EM, Topoleski TA, Yaghoubian R, et al. Orthotic treatment of infantile tibia vara. *J Pediatr Orthop*. 1998;18:670–674.
7. Blount WP. Tibia vara: osteochondrosis deformans tibiae. *J Bone Joint Surg Am*. 1937;19:1–29.
8. 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.
9. Jones S, Hosalkar HS, Hill RA, et al. Relapsed infantile Blount's disease treated by hemiplateau elevation using the Ilizarov frame. *J Bone Joint Surg Br*. 2003;85:565–571.
10. Tavares JO, Molinero K. Elevation of medial tibial condyle for severe tibia vara. *J Pediatr Orthop B*. 2006;15:362–369.
11. Janoyer M, Jabbari H, Rouvillain JL, et al. Infantile Blount's disease treated by hemiplateau elevation and epiphyseal distraction using a specific external fixator: preliminary report. *J Pediatr Orthop B*. 2007;16:273–280.
12. Beck CL, Burke SW, Roberts JM, et al. Physeal bridge resection in infantile Blount disease. *J Pediatr Orthop*. 1987;7:161–163.
13. 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.
14. Gregosiewicz A, Wośko I, Kandzierski G, et al. Double-elevating osteotomy of tibiae in the treatment of severe cases of Blount's disease. *J Pediatr Orthop*. 1989;9:178–181.
15. Accadbled F, Laville JM, Harper L. One-step treatment for evolved Blount's disease: four cases and review of the literature. *J Pediatr Orthop*. 2003;23:747–752.
16. Hefny H, Shalaby H, El-Kawy S, et al. A new double elevating osteotomy in management of severe neglected infantile tibia vara using the Ilizarov technique. *J Pediatr Orthop*. 2006;26:233–237.
17. Andrade N, Johnston CE. Medial epiphysiolysis in severe infantile tibia vara. *J Pediatr Orthop*. 2006;26:652–658.
18. McCarthy JJ, MacIntyre NR, Hooks B, et al. Double osteotomy for the treatment of severe Blount disease. *J Pediatr Orthop*. 2009;29:115–119.
19. Hofmann A, Jones RE, Herring JA. Blount's disease after skeletal maturity. *J Bone Joint Surg Am*. 1982;64:1004–1009.
20. Sabharwal S. Blount disease. *J Bone Joint Surg Am*. 2009;91: 1758–1776.
21. Langenskiöld A. Tibia vara; (osteochondrosis deformans tibiae); a survey of 23 cases. *Acta Chir Scand*. 1952;103:1–22.
22. Gugenheim JJ. Clinical evaluation including imaging. In: Sabharwal S, ed. *Pediatric Lower Limb Deformities*. New York, NY: Springer International Publishing; 2016:15–36.
23. Brown GA, Amendola A. Radiographic evaluation and preoperative planning for high tibial osteotomies. *Oper Tech Sports Med*. 2000;8:2–14.
24. Ferrick MR, Birch JG, Albright M. Correction of non-Blount's angular knee deformity by permanent hemiepiphyseodesis. *J Pediatr Orthop*. 2004;24:397–402.
25. Rozbruch SR, Hamdy RC. *Limb Lengthening and Reconstruction Case Atlas*. New York, NY: Springer International Publishing; 2015:xxxiii–Liii.
26. George D, Mallery P. *SPSS for Windows Step by Step: A Simple Guide and Reference 110 Update*, 4th ed. Boston, MA: Allyn & Bacon; 2003.
27. Graham B, Green A, James M, et al. Measuring patient satisfaction in orthopaedic surgery. *J Bone Joint Surg Am*. 2015;97: 80–84.
28. van Huyssteen AL, Hastings CJ, Olesak M, et al. Double-elevating osteotomy for late-presenting infantile Blount's disease. *J Bone Joint Surg Br*. 2005;87:710–715.
29. Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of uniapical angular deformities of the tibia or femur. *Clin Orthop Relat Res*. 1992;280:48–64.