Distal Tibial Guided Growth for Anterolateral Bowing of the Tibia: Fracture May Be Prevented

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Background: Congenital pseudarthrosis of the tibia is a rare and challenging pediatric condition. The pre-fracture state, called congenital tibial dysplasia or anterolateral bowing of the tibia, presents a high fracture risk due to underlying bowing and dysplasia. After fracture, there is a substantial risk of nonunion. Any union achieved may be complicated by refracture, deformity, leg-length discrepancy, stiffness, pain, and dysfunction. We present the results of using distal tibial growth modulation to improve tibial alignment and to decrease fracture risk in this condition. To our knowledge, this is the first report of isolated distal tibial growth modulation as the primary surgical treatment for this condition.

Methods: This is a retrospective study of 10 patients with congenital tibial dysplasia who presented prior to pseudarthrosis and underwent distal tibial growth modulation as a primary treatment. The medical records and radiographs were reviewed for age at the times of diagnosis and treatment, fracture, secondary procedures, complications, residual deformity, cystic changes, and leg-length discrepancy.

Results: Ten patients had a mean follow-up (and standard deviation) of 5.1 ± 1.9 years. No patient sustained a tibial fracture, and no patient developed a tibial pseudarthrosis after guided growth was initiated. The mean age at the initiation of growth modulation was 2.6 ± 1.3 years. Six patients required a plate exchange. The mean residual tibial diaphyseal angular deformity at the most recent follow-up was 4.3° ± 3.2° of varus and 8.4° ± 5.8° in the sagittal plane. Only 1 patient had a clinically important leg-length discrepancy, with the affected leg being longer.

Conclusions: In this series of 10 patients with congenital tibial dysplasia, distal tibial growth modulation delayed or possibly prevented fracture, decreased tibial malalignment, improved radiographic appearance of bone quality, and preserved leg length. No patient developed tibial fracture or pseudarthrosis after the initiation of guided growth treatment. Although early results are promising, follow-up to maturity is required to define the exact role of this simple outpatient procedure in congenital tibial dysplasia.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Congenital pseudarthrosis of the tibia is one of the most challenging problems facing pediatric orthopaedic surgeons. The condition is rare[1,2], and there is an associated underlying diagnosis of neurofibromatosis type 1 (NF-1) in >60% of cases[3,4]. Congenital pseudarthrosis of the tibia involves a nonunion at an apex of dysplastic bone, an ominous combination of poor bone biology and an unfavorable biomechanical environment. The precursor to congenital pseudarthrosis of the tibia is a pre-pseudarthrosis state, called anterolateral bowing of the tibia or congenital tibial dysplasia. The natural history of this condition typically involves early fracture, frequently by the age of 2 or 3 years[3-5]. Reported efforts to delay or reduce the risk of fracture include orthosis use[6-8], bypass grafting[8-11], and a recent single case report of combined proximal and distal tibial growth modulation[12]. Once fracture occurs, the primary goal of treatment is to achieve and maintain union, as the refracture rate is high[3-5,13-19]. There are 3 major categories of surgical procedures frequently used to achieve union: (1) pseudarthrosis resection, bone-grafting, and intramedullary fixation[5,16,18,20-22]; (2) pseudarthrosis resection with circular external fixation[14,15,23,24]; and (3) vascularized fibular grafting[19,23,25].

Repeated surgical procedures, chronic nonunion, and long periods of disuse put patients at risk for pain, deformity, and disability. This can include leg-length discrepancy, residual angular deformity, ankle stiffness, foot deformity, and gait dysfunction. These long-term risks, coupled with the psychosocial

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cost of repeated surgical procedures, have led some authors to advocate for an early discussion of amputation[26-30].

Based on the natural history of congenital tibial dysplasia, when a child presents in a pre-fracture state, preventing or delaying fracture is of the utmost importance. Upon diagnosis, most surgeons initiate a clamshell ankle-foot orthosis (AFO) as the first-line treatment[6-8]. This nonoperative measure attempts to delay fracture on the basis of evidence that late-onset fracture is associated with a milder clinical course[18,31] and better gait function[32]. There have been limited reports of fracture-free success with orthotic use[7,33,34], and, to our knowledge, there have been no long-term studies assessing bracing as the primary treatment for this condition. Despite bracing, many children proceed to fracture, with or without the orthosis in place[7,8,35].

Surgical options for fracture prevention have variable results. Corrective osteotomy at the apex of the deformity to prevent future fracture has often led to iatrogenic pseudarthrosis[28,36]. Some surgeons have utilized a fibular graft (the McFarland bypass procedure)[9] to provide a mechanical strut to the bowed tibia. The success rates for this technique in preventing fracture have been varied[8,10,11], with high rates of residual deformity[8,10]. One study showed that 100% of patients were pseudarthrosis-free after a mean time of 78 months[8]. A recent report demonstrated successful tibial growth modulation at the proximal and distal physes in a single case of anterolateral bowing of the tibia[12]. At the 4-year follow-up, the child had improved alignment and no evidence of fracture.

At our institution, the senior author (M.T.D.) began using guided growth at the distal tibial physis in 2011 for pre-pseudarthrosis congenital tibial dysplasia in an effort to decrease the risk of fracture through improving mechanical alignment. The purpose of this study was to evaluate the early experience with distal tibial growth modulation for congenital tibial dysplasia. Our primary question was whether this technique prevented or delayed fracture in patients presenting with anterolateral bowing of the tibia compared with the known natural history[11,37,38]. Our 3 secondary questions were: (1) whether patients undergoing guided growth required any secondary procedures or unanticipated procedures or had any complications associated with guided growth, (2) whether patients undergoing this treatment had residual angular deformity or leg-length discrepancy, and (3) whether fibular procedures were performed during the follow-up period.

Materials and Methods

Study Design

All patients evaluated clinically by 3 orthopaedic surgeons (M.T.D., E.W.W., and J.C.L.) at our institution for anterolateral bowing of the tibia or congenital tibial dysplasia between January 1, 2011, and December 31, 2017, were assessed for eligibility. Ten pediatric patients with anterolateral bowing of the tibia without tibial pseudarthrosis who underwent initiation of guided growth of the distal tibial physis as a primary treatment were identified, and a retrospective clinical and radiographic review was performed. Patients were not considered candidates for guided growth if they had an unstable tibial fracture, congenital pseudarthrosis of the tibia, or complex deformity not amenable to guided growth. Anteroposterior and lateral radiographs of the tibia were acquired before the surgical procedure and throughout treatment per the standard of care. Charts were reviewed for demographic information; diagnosis; age at the times of diagnosis, surgical procedure, and the most recent follow-up; fracture; clinical findings; surgical interventions; and complications. Complications were assessed using the Clavien-Dindo system[39,40]. The duration of treatment was defined as the time between plate insertion and final plate removal.

This study was conducted in accordance with the World Medical Association Declaration of Helsinki[41] and was approved by our institutional review board with a waiver for informed consent.

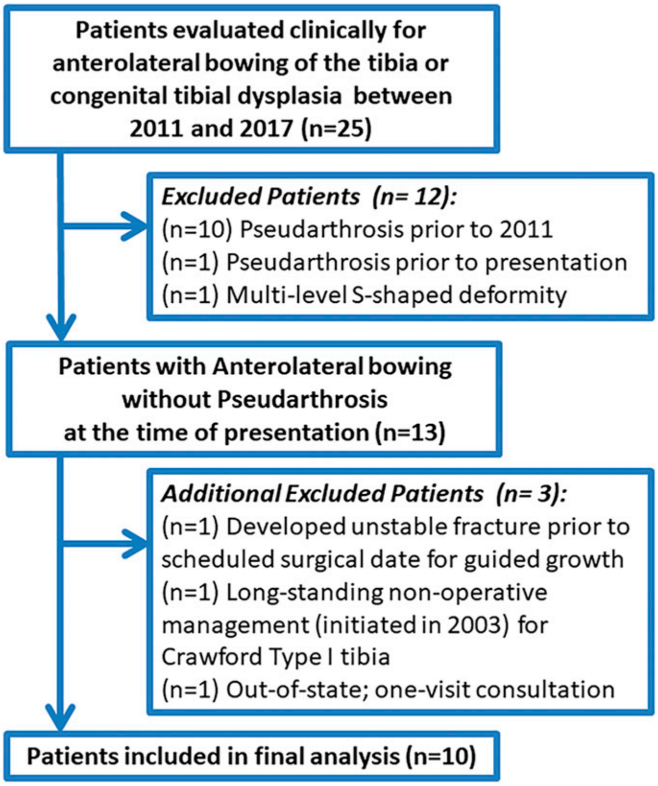

Fig. 1

Patient flowchart. To ensure adequate patient capture, all patients who were evaluated by the 3 surgeons for anterolateral bowing of the tibia (ALBT) or congenital tibial dysplasia (CTD) during the treatment window were assessed for eligibility. Guided growth was only considered to be indicated for patients without pseudarthrosis and/or without unstable fracture, so 12 patients were excluded. Of the remaining 13 patients, 1 had a complex, multilevel deformity that was not amenable to guided growth; 1 was identified who had shown gradual improvement in tibial deformity with nonoperative management since 2003, so her course remained nonoperative; and 1 was from out of state and only had 1 consultation visit. We considered the remaining 10 patients to be a consecutive series of distal tibial guided growth for this condition.

TABLE I Preoperative Demographic Characteristics and Lower-Extremity Involvement*

Patient	Age at Diagnosis *(mo)*	Age at Surgery *(yr)*	Sex	Laterality	Diagnosis of NF-1	Previous Unstable Tibial Fracture	Crawford Classification Type	Fibular Involvement
1	16	2.7	F	L	No	No*	III	Dysplastic
2	6	1.9	M	R	Yes	No	II	Normal
3	1	1.1	M	R	Yes	No	III	Normal
4	2	2.0	M	L	Yes	No	III	Normal
5	24	2.3	M	L	Yes	No	I	Dysplastic
6	15	6.0	M	R	No	No	II	Pseudarthrosis
7	9	2.0	F	R	Yes	No	II	Pseudarthrosis
8	21	2.2	M	R	Yes	No	III	Dysplastic
9	25	2.4	M	L	No	No	II	Normal
10	0†	3.2	M	L	No	No	II	Normal

*Patient 1 had a nondisplaced, stable tibial fracture prior to treatment; stability was confirmed with stress under fluoroscopy. †This patient had a prenatal diagnosis of congenital tibial dysplasia.

Surgical Technique

Preoperative planning included determining the point of maximal tibial bowing in an oblique plane as described by Dahl[42] to establish the appropriate location of the tension band plate[43].

Procedures were performed under general anesthesia and tourniquet control in an outpatient setting. A 1 to 2-cm incision was made over the distal tibial physis anterolaterally, in line with the plane of maximal deformity. The 12-mm plate (eight-Plate Guided Growth System; ORTHOFIX) was placed extraperiosteally along the true plane of deformity as measured with a sterile goniometer. Because of the relatively small target, the longest possible 4.5-mm cannulated screw was first placed in the epiphysis (of note, 3.5-mm screws were utilized in 1 case). With the distal hole in the plate centered on the partially advanced epiphyseal screw, the plate was positioned vertically, and the metaphyseal screw was placed. Using an alternating tightening technique, both screws were advanced until the plate was secure. An arthrogram was considered if improved epiphyseal visualization was needed. After wound closure, the patient was placed in a soft dressing, the prior orthosis, or short leg immobilization (1 to 4 weeks), depending on the surgeon's preference. All patients with bracing were returned to their clamshell AFO within 4 weeks.

Patients were typically followed at 3-month intervals clinically and radiographically. Plate exchange was necessary if the screw encroached on the distal tibial physis or if the screws

TABLE II Summary of Guided Growth Treatment*

Patient	Follow-up Duration† *(yr)*	Age at Final Follow-up *(yr)*	Duration of Growth Modulation† *(mo)*	No. of Plate Exchanges	Time to First Plate Exchange *(mo)*	Time to Second Plate Exchange† *(mo)*	Recurrent Deformity Requiring Treatment	Unanticipated Return to Operating Room	Additional Tibial Procedures	Tibial Fracture	Complications (Modified Clavien-Dindo Classification[39,40])
1	8.1	10.8	25.2	1	9.2	NA	No	No	No	No	—
2	7.6	9.5	21.8	1	8.2	NA	No	No	No	No	—
3	6.2	7.3	23.4	1	8.6	NA	No	No	No	No	I‡
4	6.1	8.1	13.2	1	9.0	NA	No	Yes§	No	No	IIIb#
5	5.5	7.8	26.2**	0	NA	NA	Yes††	No	No	No	—
6	3.9	9.9	11.5	0	NA	NA	No	No	No	No	—
7	4.0	6.0	14.5	1	7.7	NA	No	No	No	No	I‡, I‡‡
8	3.6	5.7	11.3	0	NA	NA	No	No	No	No	—
9	2.7	5.1	29.3	0	NA	NA	No	No	No	No	—
10	2.9	6.1	NA	2	9.5	34.7	No	No	No	No	—

*NA = not applicable. †Time since the index surgical procedure. ‡This patient had an unscheduled clinic visit due to postoperative pain, treated with analgesic medications and immobilization adjustment. §This patient underwent an implant revision that was performed because of screw encroachment on the distal tibial physis. #This patient had an unanticipated return to the operating room due to screw migration into the physis after an implant revision. **This is the sum of 2 temporally distinct episodes of guided growth treatment (1 episode at 12.2 months and 1 episode at 14.0 months). ††Recurrent deformity precipitated repeat guided growth 39 months after the index surgical procedure. ‡‡This patient had an unscheduled clinic visit due to postoperative incisional maceration after walking in a brace, treated with observation.

became too far splayed to guide growth effectively. For plate exchange, a new plate and screws were inserted, taking care to use new guidewire holes. Guided growth was continued until the tibial physis and ankle were parallel to the floor and the anatomic axis and mechanical axis of the tibia had been improved. Orthotic use was typically recommended until skeletal maturity, although surgeons tolerated self-discontinuation of bracing once satisfactory alignment had been achieved.

Radiographic Measurements

The medial proximal tibial angle, lateral distal tibial angle, anterior distal tibial angle, and mechanical axis deviation were measured on digital radiographs according to standard deformity analysis. Leg lengths were measured on standing alignment radiographs from the superior aspect of the femoral head to the center of the distal tibial plafond. Anatomic tibial diaphyseal alignment was measured on anteroposterior views to assess diaphyseal coronal angulation and on lateral views to assess diaphyseal sagittal angulation. All radiographs of the tibia and fibula throughout the duration of care were assessed for fractures, cysts, and recurrent deformity. The radiographic appearance of the tibia was assessed using the Crawford classification[28,44]. The fibula was assessed radiographically for signs of dysplasia, bowing, and overgrowth.

Statistical Analyses

Demographic characteristics and radiographic measurements were analyzed using descriptive statistics.

Results

Ten children underwent distal tibial guided growth for anterolateral bowing of the tibia or congenital tibial dysplasia (Fig. 1). The mean age (and standard deviation) at the time of diagnosis was 11.9 ± 9.6 months, and the mean age at the time of the first surgical growth modulation was 2.6 ± 1.3 years (Table I). Sixty percent of children had an underlying diagnosis of NF-1, and 80% of patients were boys. Only 1 patient had a confirmed tibial fracture on the affected side prior to initiating

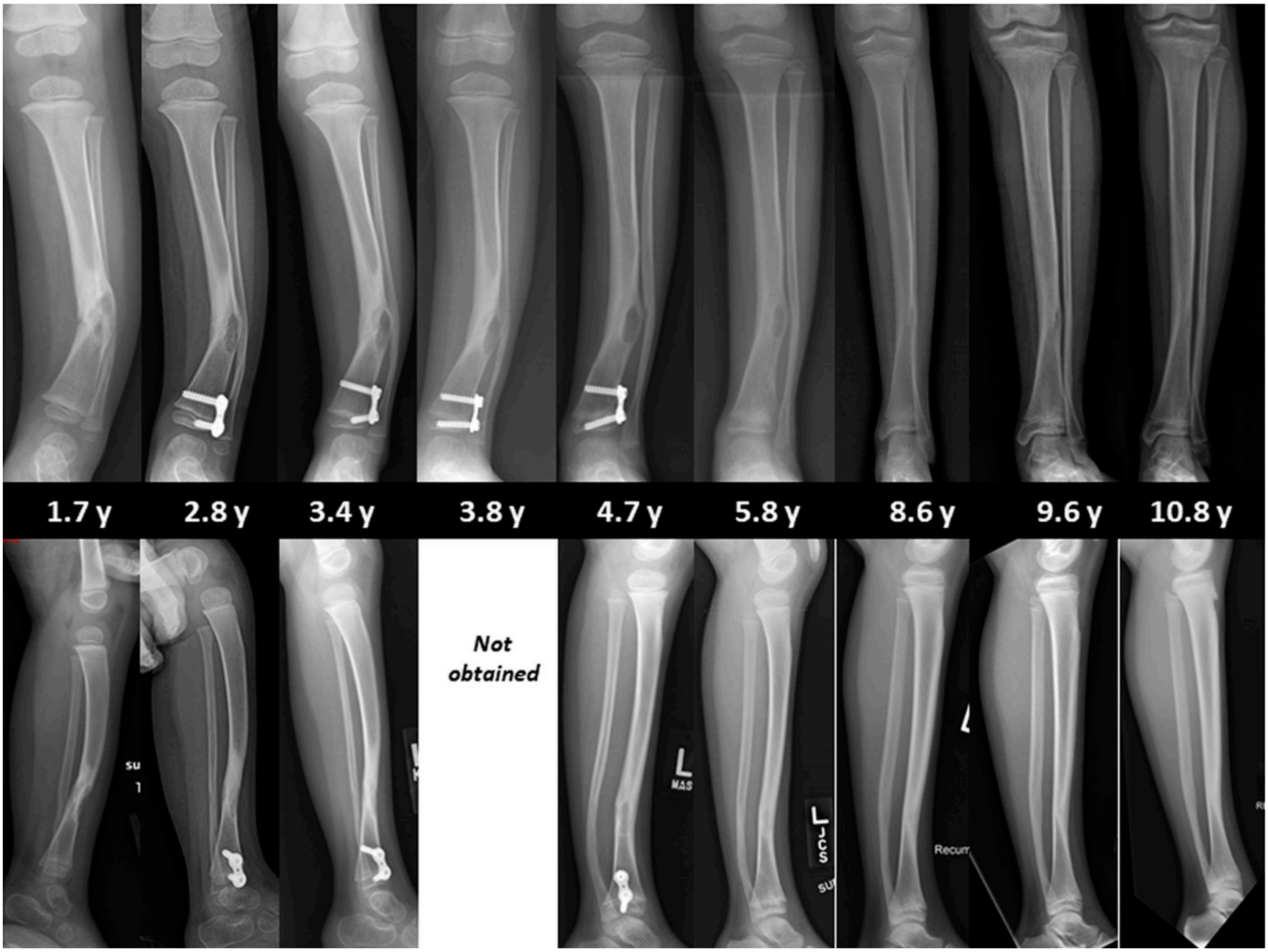

Fig. 2

Serial radiographs of Patient 1 from the age of 1.7 years to 10.8 years.

growth modulation, although this remained minimally displaced and stable (Table I). At the initiation of treatment, 1 child had a Crawford Type-I tibia, 5 children had a Crawford Type-II tibia, and 4 children had a Crawford Type-III tibia (Table I).

After the initiation of growth modulation, no patient sustained a tibial fracture (Table II) and no patient developed a tibial pseudarthrosis. The mean follow-up from the index procedure was 5.1 ± 1.9 years (range, 2.7 to 8.1 years) (Table II).

At the most recent follow-up, 1 patient continued to undergo growth modulation (Patient 10), and 2 patients were undergoing active treatment for fibular pseudarthrosis (Patients 6 and 8). During growth modulation treatment, 60% of patients required plate exchange, and 1 patient required 2 plate exchanges (Table II). All patients requiring plate exchange underwent this procedure in the first year of treatment, at a mean time of 8.7 ± 0.7 months (Table II). Patient 5 underwent a second course of growth modulation due to recurrent ankle varus deformity associated with an overgrown fibula. The total mean duration of growth modulation, excluding the patient still in treatment, was 19.6 ± 7.0 months (Table II). There was 1 case of unanticipated return to the operating room for screw encroachment on the physis, identified shortly after plate exchange (Patient 4) (Table II). No patient underwent a tibial procedure other than procedures related to growth modulation.

Tibial alignment improved in all children (Figs. 2 through 5, Table III). The mean tibial diaphyseal angulation at the time of the final follow-up, excluding the patient still in treatment, was 4.3° ± 3.2° of varus (Fig. 4-A) and 8.4° ± 5.8° of sagittal plane angulation (5° recurvatum to 16° procurvatum) (Fig. 4-B). Individual changes are shown for the lateral distal tibial angle (Fig. 4-C) and the anterior distal tibial angle (Fig. 4-D). All but 1 patient achieved a satisfactory mechanical axis of the lower extremity (Table III), with the latter patient demonstrating excessive genu valgum (Patient 2) (Fig. 3). Only 1 child had a clinically important leg-length discrepancy at the most recent follow-up, with the affected extremity being longer (Patient 5) (Fig. 5, Table III). Before treatment, this child's affected extremity was 1.2 cm longer than the unaffected extremity.

Of the 4 children who presented with cystic changes, the cysts completely resolved in 3 children and nearly resolved in the remaining child (Fig. 6, Table IV). There were 6 Crawford Type-I tibiae at the time of the final follow-up.

Fifty percent of children had fibular involvement preoperatively (Table V). At the most recent follow-up, 1 child had an untreated fibular pseudarthrosis (Patient 7) and 2 children

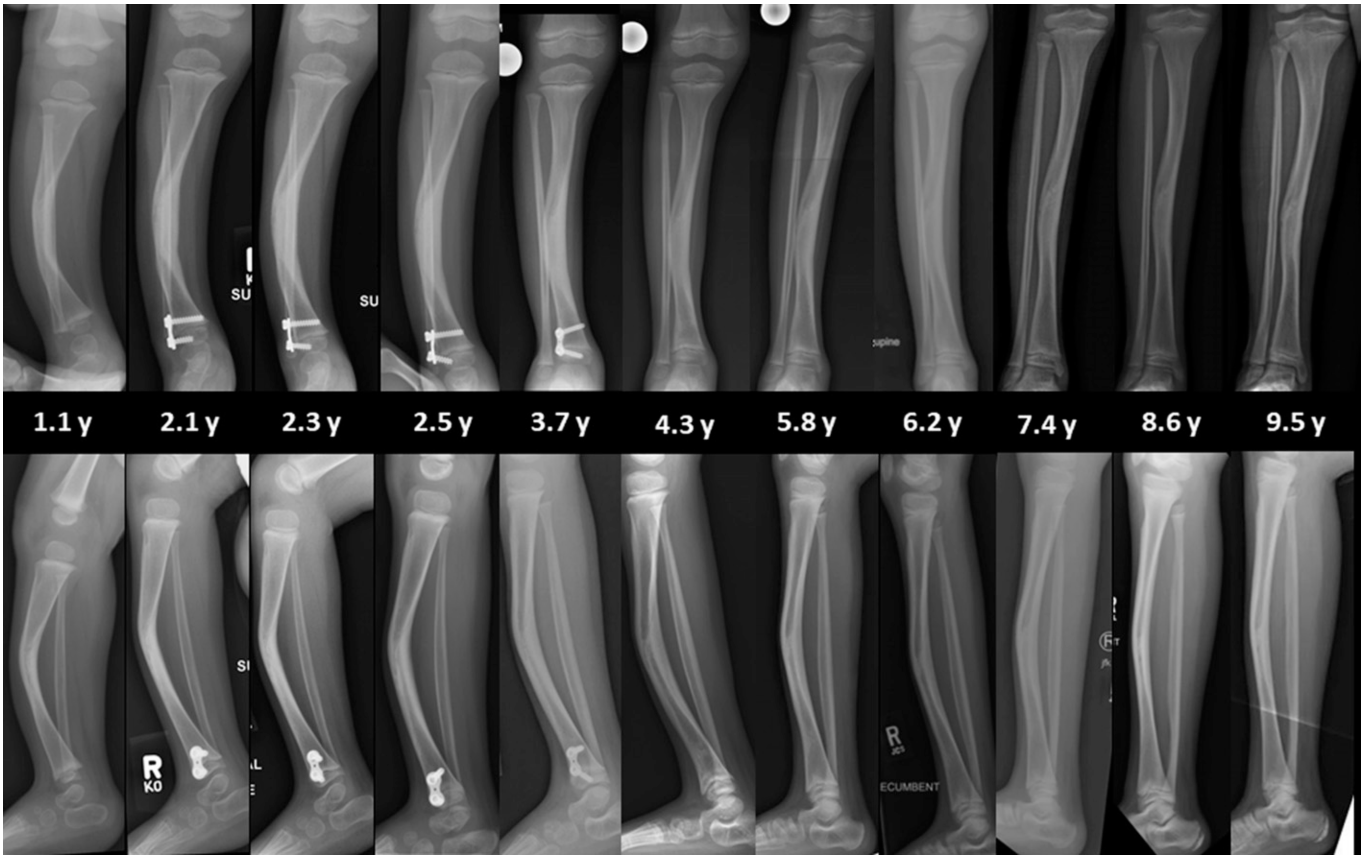

Fig. 3

Serial radiographs of Patient 2 from the age of 1.1 years to 9.5 years. This patient has residual proximal tibial valgus and will require growth modulation for genu valgum.

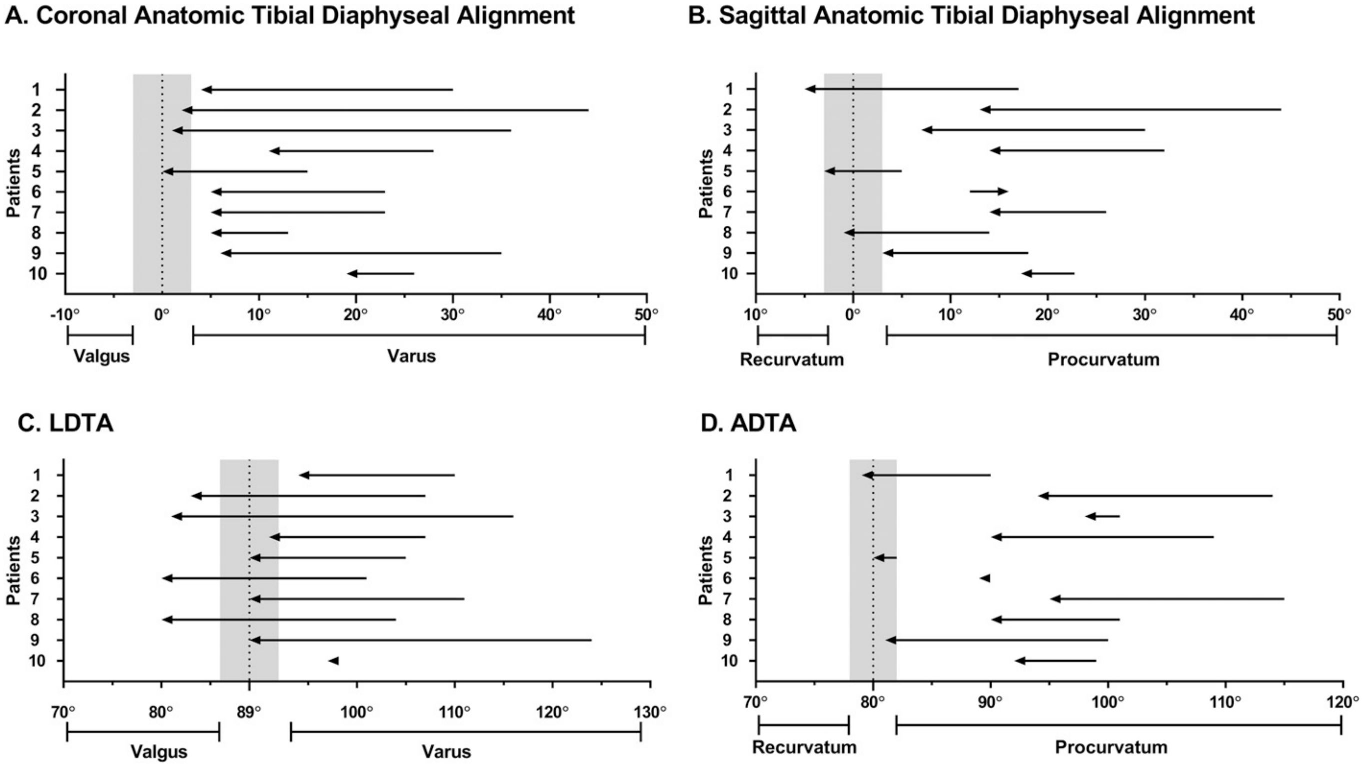

Fig. 4

Figs. 4-A through 4-D Changes in radiographic measurements of tibial alignment: coronal (**Fig. 4-A**) and sagittal (**Fig. 4-B**) tibial diaphyseal alignment, lateral distal tibial angle (LDTA) (**Fig. 4-C**), and anterior distal tibial angle (ADTA) (**Fig. 4-D**). Arrows represent the change from the preoperative measurement to the most recent radiographic follow-up.

were undergoing active treatment for fibular pseudarthrosis (Patients 6 and 8) (Table V). One patient (Patient 1) had mild bowing of the fibula (Fig. 2), and 1 patient (Patient 5) had a bowed, dysplastic, long fibula despite temporary fibular epiphysiodesis.

Discussion

In this series of 10 patients with anterolateral bowing of the tibia or congenital tibial dysplasia with a mean follow-up of 5 years, no patient developed tibial fracture or pseudarthrosis after the initiation of guided growth treatment in conjunction

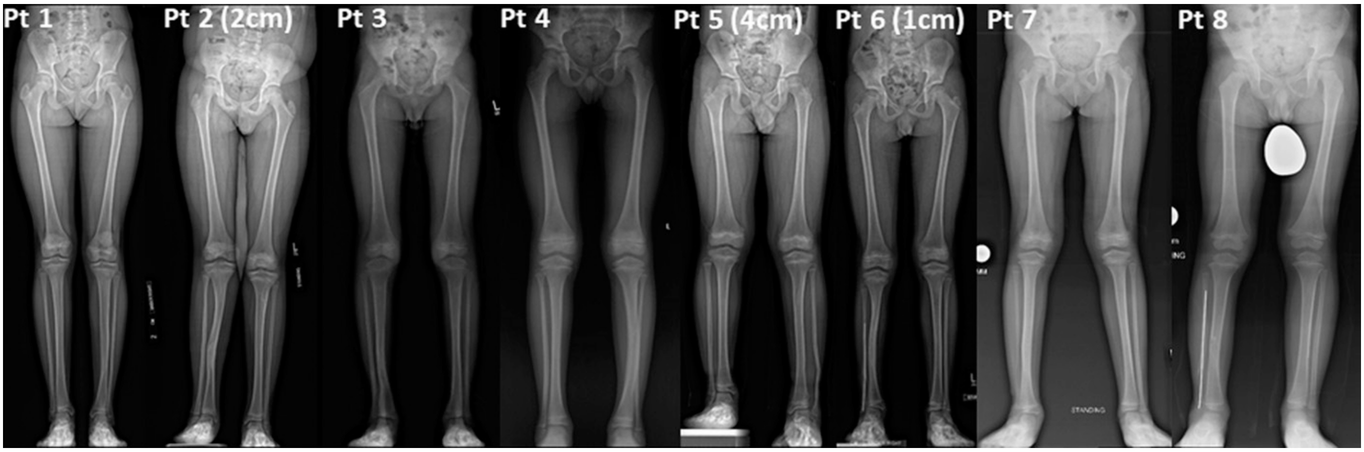

Fig. 5

Final standing alignment radiographs of Patients 1 through 8. The block size is indicated in parentheses. Patients 1, 2, 4, and 5 have greater length on the affected side. Patient 5 has the only clinically important leg-length discrepancy, with the affected extremity being 3.6 cm longer. Patients 6 and 8 have an affected extremity that is shorter. Pt = patient.

TABLE III Radiographic Measurements of Residual Deformity at the Final Follow-up*

Patient	Coronal Tibial Diaphyseal Angulation and Direction	Medial Proximal Tibial Angle	Lateral Distal Tibial Angle	Sagittal Tibial Diaphyseal Angulation and Direction	Anterior Distal Tibial Angle	Mechanical Axis Deviation *(mm)* and Direction	Leg-Length Discrepancy† *(cm)*
1	4° varus	88°	94°	5° recurvatum	79°	5 valgus	−0.4
2	2° varus	95°	83°	13° procurvatum	94°	27 valgus	−0.5
3	1° varus	91°	81°	7° procurvatum	98°	6 varus	0
4	11° varus	88°	91°	14° procurvatum	90°	0	−0.6
5	0°	90°	89°	3° recurvatum	80°	2 valgus	−3.6
6	5° varus	91°	80°	16° procurvatum	89°	7 valgus	1.6
7	5° varus	86°	89°	14° procurvatum	95°	2 valgus	0
8	5° varus	89°	80°	1° recurvatum	90°	3 valgus	0.1
9	6° varus	86°	89°	3° procurvatum	81°	NA‡	1.0‡
10§	NA	NA	NA	NA	NA	NA	NA

*NA = not available. †Negative values indicate that the affected leg is longer, and positive values indicate that the affected leg is shorter. ‡A full-length standing alignment radiograph was not obtained at the most recent visit; the mechanical axis deviation measurement was therefore not available, and the leg-length discrepancy measurement was a clinical measurement only, although consistent with previous radiographic examinations. §Patient 10 was still in treatment, so the final measurements were not available at the time of this writing.

with bracing. Distal tibial growth modulation decreased tibial malalignment, improved radiographic appearance of dysplastic bone, and preserved length. Congenital tibial dysplasia is considered to be not only a mechanical problem, but also a biologic one[29,35,45]. In the present study, improvements in the mechanical alignment of the tibia and the preservation of weight-bearing status appeared to resolve cysts and resulted in improvements in radiographic classification for many of the patients.

Anterolateral bowing and the associated dysplastic bone predispose the tibia to fracture, with studies citing a mean age of first fracture between 2 and 3 years[4,5]. A recent meta-analysis showed that 75% of patients achieve primary union after fracture, but that union is tenuous, with 35% of those unions proceeding to refracture[3]. Other longer-term follow-up studies have shown even higher refracture rates[4,16,18].

Many authors have agreed that fracturing at an older age may be less problematic[18,31,32,46]. Dobbs et al.[18] reported a lower refracture rate in children who were older at the time of pseudarthrosis. Roach et al.[31] reported on 11 cases of late-onset pseudarthrosis, describing these cases as a milder form of the condition with a better prognosis. Karol et al.[32] reported improved gait function in patients who had a first fracture at an age of ≥4 years. They noted that this delayed-onset group had fewer surgical interventions and less frequently required trans-ankle fixation, likely leading to better gait compared with the early-onset group.

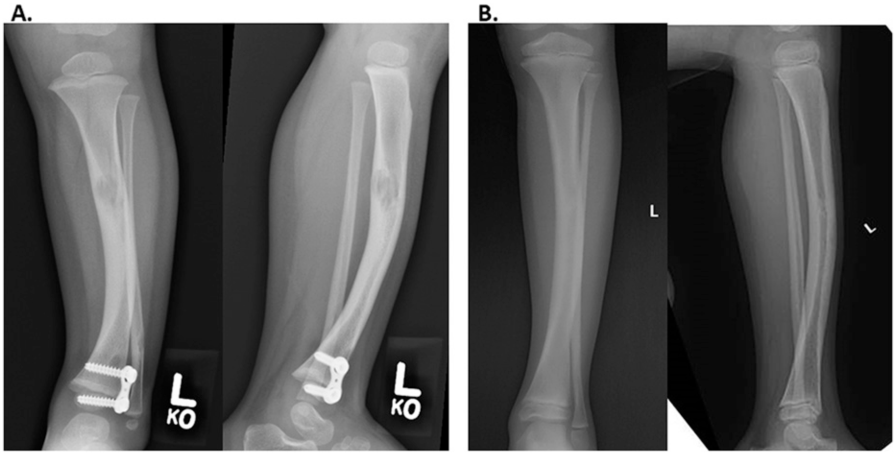

Fig. 6

Figs. 6-A and 6-B Largest remaining cysts at the final follow-up for Patient 4. Radiographs were obtained at 2.3 years of age (**Fig. 6-A**) and 8.1 years of age (**Fig. 6-B**).

TABLE IV Radiographic Outcomes*

	Cyst Height × Width *(mm)*		Crawford Classification		Tibial Pseudarthrosis
Patient	Preoperative	Final Follow-up	Preoperative	Final Follow-up	Final Follow-up
1	22.1 × 7.8	—	III	I	No
2	—	—	II	I	No
3	23.5 × 6.8	—	III	I	No
4	26.9 × 8.2	4 × 1.2†	III	III	No
5	—	—	I	I	No
6	—	—	II	II	No
7	—	—	II	I	No
8	10.8 × 8	—	III	II	No
9	—	—	II	I	No
10	—	—	II	NA	No

*NA = not available. †Overall, the appearance of the tibia is consistent with Crawford Type I, but a very small cyst remains (Fig. 6).

One fracture-prevention technique is the McFarland procedure[9], using an allogenic strut graft to bypass the deformed segment of the tibia. Success with this technique has been variable. In a multicenter study by the European Paediatric Orthopaedic Society (EPOS), Grill et al.[10] reported 19 cases of the McFarland procedure, with 7 intact tibiae at the end of treatment, and only 1 tibia was "straight." Strong and Wong-Chung[11] reported success in 6 of 9 cases in which the McFarland procedure was used prophylactically. Ofluoglu et al.[8] reported 10 of 10 successful cases of modified McFarland bypass grafting in pre-pseudarthrosis tibiae at a mean follow-up of 78 months. Although no patient sustained tibial fracture after bypass treatment, residual deformity persisted: the mean coronal diaphyseal angulation was 25.7°, and sagittal angulation was 27.5°. However, even though the fracture rate in the present study was equivalent (0%), guided growth left less residual deformity, with diaphyseal angulation of 4.1° in the coronal plane

TABLE V Fibular Deformity and Treatment*

	Fibular Involvement			
Patient	Preoperative	Final Follow-up	No. of Procedures	Fibular Treatment Summary
1	Dysplastic	Mild bowing	0	None
2	Normal	Normal	0	None
3	Normal	Normal	0	None
4	Normal	Normal	0	None
5	Dysplastic, bowed, long	Dysplastic, bowed, long	3	(1) Screw epiphysiodesis fibula (2) Screw exchange (3) Screw removal
6	Pseudarthrosis	Pseudarthrosis healing with intramedullary fixation in place	1	Resection, reconstruction, bone-grafting, BMP-2, and intramedullary fixation
7	Pseudarthrosis	Pseudarthrosis	0	None
8	Dysplastic	Pseudarthrosis healing with intramedullary fixation in place	3 procedures, 4 major elements of treatment	(1) Resection and osteotomy, bone graft, intramedullary fixation (2) Intramedullary pin revision (3) Bone-grafting to create synostosis, revision intramedullary fixation (4) Bisphosphonate treatment
9	Normal	Normal	0	None
10	Normal	Normal	0	None

*BMP-2 = bone morphogenetic protein 2.

and 9.1° in the sagittal plane. Additionally, the guided growth procedures were substantially less invasive and required less postoperative immobilization than the McFarland technique.

The most similar study with respect to the treatment described herein is a single case report of proximal and distal tibial growth modulation for anterolateral bowing of the tibia[12]. At the most recent follow-up, 1 patient in our series of distal-only growth modulation had an abnormal medial proximal tibial angle and genu valgum, but all other patients had a normal medial proximal tibial angle, suggesting that the proximal plate is unnecessary in most cases. Both studies demonstrated the successful effect of growth modulation on the relatively distant diaphyseal deformities, with the benefit of leaving the soft-tissue envelope surrounding the apex of the deformity untouched.

Multiple studies have shown marked limb-shortening at the end of treatment[3,6,10,17,18,47]. Many of the surgical interventions involve resection of the pseudarthrosis and, therefore, tibial shortening. Decreased weight-bearing is also presumed to slow distal tibial growth[48]. In our study, the majority of the leg-length discrepancies involved the affected leg being longer than the unaffected leg. In fact, the only clinically important leg-length discrepancy in the series involved the affected extremity measuring 3.6 cm longer than the unaffected extremity. By avoiding surgical shortening and by maintaining weight-bearing in the extremity, this study suggests that limb-shortening is not an inherent risk of congenital tibial dysplasia, but may be iatrogenic or secondary. Growth modulation appears to preserve the length of the affected extremity.

Although the sample size was too small to report definitively, it does not appear that guided growth of the distal tibial physis has appreciable impact on the natural history of the fibula. In a large, multicenter study, fibular involvement was seen in 62% of patients[49], similar to the 50% involvement in our patient cohort. In the present study, 1 patient underwent fibular epiphysiodesis for overgrowth, 2 patients were undergoing active treatment for fibular pseudarthrosis management, and 1 patient had a fibular pseudarthrosis that had not been treated as of the time of this writing. Although tibial dysplasia improved in all 10 patients in this series, 4 of the 5 patients who presented with fibular dysplasia or pseudarthrosis continued to have notable fibular abnormality at the most recent follow-up. Additionally, Patients 6 and 8, who were undergoing active fibular treatment, also had the 2 lowest lateral distal tibial angle measurements (each with 80°).

The strength of this study is that it is a consecutive series of patients undergoing distal tibial growth modulation to treat congenital tibial dysplasia. Because of the rarity of this condition and the frequency of early fracture, a series of 10 patients prior to pseudarthrosis at 1 institution constituted a large series.

The limitations of this study were consistent with those of other retrospective studies. We were limited by the data available in the medical record and radiographs. The sample size was too small for meaningful statistical analyses, and there was no comparison group other than historic controls in the literature. Many authors have stressed the importance of follow-up to skeletal maturity in cases of congenital pseudarthrosis of the tibia[5,29,34,36,46], although this was often in reference to the risk of late refracture. Even if this technique only delays fracture, this is still of great benefit in improving long-term prognosis and function[18,31,32]. Lloyd-Roberts and Shaw[37] emphasized: “it should not be forgotten that it is exceptional for the first fracture to be late, for most occur within the first year or two.” All 10 patients will be followed for signs of late deformity, leg-length discrepancy, and premature physeal arrest. Further study of this technique for congenital tibial dysplasia in other centers is warranted, including a greater number of patients and follow-up until skeletal maturity.

In conclusion, we recommend distal tibial guided growth for patients with congenital tibial dysplasia in a pre-pseudarthrosis state in order to delay or possibly prevent fracture, to improve tibial alignment, and to decrease the radiographic signs of dysplasia. The technique is familiar to most pediatric orthopaedic surgeons, is an outpatient procedure, is minimally invasive, and does not injure or risk the pathologic apical bone and the surrounding soft tissues. Growth modulation in this population requires close follow-up, as implant exchange is frequently required. Distal tibial growth modulation seems to provide a functional, fracture-free extremity while still minimizing burden. We hope that the information presented herein may lead to fewer fractures and decreased morbidity in this patient population. At our institution, distal tibial growth modulation in combination with orthosis use is now offered as a first-line treatment to all patients presenting with pre-fracture congenital tibial dysplasia. ■

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