

Acute correction of proximal tibial coronal plane deformity in small children using a small monolateral external fixator with or without cross-pinning

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Abstract

Purpose: Surgical correction of proximal tibia deformity in small children can be challenging. We present the surgical technique and outcome of proximal tibia osteotomy fixed with small monolateral external fixator in this patient group.

Methods: A total of 17 cases in eight patients younger than nine years of age were study subjects. A proximal tibia osteotomy was fixed with a small monolateral external fixator with or without cross-pinning. Outcome was evaluated by changes of radiographic parameters such as medial proximal tibia angle (MPTA), metaphyseal diaphyseal angle (MDA) and clinical findings of complications, time interval until weight bearing and fixator removal time.

Results: MPTA improved from a preoperative mean of 73° (SD 4°; 66° to 78°) to an immediate postoperative mean of 90° (SD 3°; 85° to 96°) in varus tibiae, and from 104° (SD 1°; 103° to 105°) to 89° (SD 1°; 88° to 89°) in valgus tibiae. In all, 15 of the 17 cases (88.3 %) achieved postoperative MPTA within the normal range (85° to 90°). MDA improved from a preoperative mean of 19° (SD 5°; 11° to 24°) to an immediate postoperative mean of 0° (SD 4°; -6° to 7°) in varus tibiae, and from -25° (SD 2°; -22° to -24°) to 2° (SD 1°; 1° to 3°) in valgus tibiae. Full weight bearing was possible at mean 1.7 months (0.5 to 3.0). Mean follow-up period was 6.5 years (SD 5.4; 1.0 to 16.0). No complications developed during the follow-up.

Conclusion: Proximal tibia osteotomy fixed with small monolateral external fixator provides accurate, safe and effi-

cient correction in the management of coronal plane angular deformity in small children.

Level of Evidence: Level IV

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Keywords: proximal tibia osteotomy, genu varum, genu valgum, external fixator

Introduction

Physiologic genu varum or genu valgum is common in small children and remodels spontaneously with age. However, persistent and significant deformities are sometimes encountered in small children with pathological conditions such as genetic and metabolic skeletal disorders or Blount's disease. There are several surgical options, including asymmetric physeal suppression,¹ gradual correction using an external fixator² and acute correction with internal fixation.^{3,4} Asymmetric physeal suppression by temporary hemiepiphysiodesis or guided growth is a less invasive procedure, with fewer complications.^{5,6} However, in small children with genetic or metabolic skeletal disorders, it could be technically demanding for hypoplastic or dysplastic epiphysis. Moreover, it could run a theoretical risk of premature physeal arrest, or could be ineffective due to lack of growth potential of tibial physis from the underlying pathology.^{6,7} Gradual correction using an external fixator has advantages of multi-planar correction and huge correctability.^{2,8} However, external fixator for this purpose is too bulky to be applied to small children with genetic or metabolic skeletal disorders. Acute correction with internal fixation can correct angular deformity without risk of physeal involvement and bulky external fixator application. However, accurate correction and rigid fixation is difficult in small children.^{9,10} We present our experience and outcome of acute correction fixed with a small monolateral external fixator, which was devised for the adult forearm or humerus, in the management of proximal tibial coronal plane deformity for short tibia in small children.

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Materials and methods

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This retrospective study was approved by our institutional review board.

Using the database of patients admitted to our paediatric orthopaedic division from 01 January 2004 to 31 January 2019, we collected the patients by the following criteria: 1) who had undergone surgical correction for proximal tibia coronal plane angular deformity by proximal tibia osteotomy fixed with a small monolateral external fixator; 2) who were less than nine years of age; 3) who were followed for more than a year; and 4) whose clinical and radiographic data were completely available. A total of 17 tibiae in eight patients constituted the study population (Table 1). The primary diagnoses included hypophosphatemic rickets (two patients), pseudoachondroplasia (two patients), multiple epiphyseal dysplasia (one patient), metaphyseal chondrodysplasia of unspecified type (one patient), mucopolysaccharidosis type IV (one patient) and Blount's disease (one patient). A total of 15 tibiae of seven patients had varus deformity and two tibiae of one patient had valgus deformity. Mean age at operation was 6.4 years (sd 2.1; 3.7 to 8.8). Mean height was 102.2 cm (SD 10.6; 92.0 to 118.4) and mean z-score for height was -3.3 (sd 1.8; -5.9 to -0.4) at the time of index operation.¹¹ Mean tibia length at operation was 187.4 mm (SD 21.5; 161.3 to 241.9). In all tibiae, the z-score of tibial length was < -2.0.¹² Concomitant fibular osteotomy was done in 15 of 17 tibiae and prophylactic common peroneal nerve decompression was done in all cases. Simultaneous distal femoral correction was done by osteotomy with internal fixation (five cases) or temporary hemiepiphysiodesis (two cases). They were followed for an mean of 6.5 years (sd 5.4; 1.0 to 16.0).

We retrospectively reviewed medical records and radiographs. We measured radiographic parameters of medial proximal tibia angle (MPTA)¹³ and metaphyseal diaphyseal angle (MDA)¹⁴ to evaluate the coronal plane deformity change and posterior proximal tibia angle (PPTA)¹³ to evaluate the sagittal plane alignment change, on the preoperative radiographs, immediate postoperative radiographs and radiographs taken when the patients became able to bear full weight. We measured the amount of angular correction and assessed the accuracy of angular correction with a normal range of MPTA (85° to 90°).¹³ We recorded the time interval until weight bearing, fixator removal time, complications, recurrence of deformity, and surgical intervention for it.

Mean values of preoperative and postoperative MPTA, MDA and PPTA were compared using the Wilcoxon signed-

rank test (SPSS version 18.0; SPSS, Inc., Chicago, Illinois). A p-value < 0.05 was considered statically significant.

Operative technique

All operations were performed by a single surgeon (TJC). The patients were prepared under general anaesthesia in the supine position. In cases with epiphyseal dysplasia, an intraoperative arthrogram of knee joint was done to delineate the exact proximal tibia joint line. Prophylactic peroneal nerve decompression¹⁵ was done. The fibular osteotomy was performed through the same or separate skin incision to allow easier tibia deformity correction. The level of fibular osteotomy was between the tibia osteotomy site and proximal one-third of the fibula.

For tibia osteotomy fixation, half pins of 2.7 mm or 3.3 mm in diameter were selected depending on the tibial size. A proximal half pin was inserted parallel to the proximal joint line on the coronal plane and behind the tibial tuberosity to avoid damage to its physis. Two distal pins were placed at the diaphysis, perpendicular to the tibia shaft and parallel to the proximal pins on the horizontal plane. A second proximal half pin was inserted parallel to the first one if the tibia was big enough. Two half pins were inserted to the proximal fragment in 11 cases and only one half pin in six cases. Proximal tibia osteotomy was made through a transverse curvilinear skin incision just below the tibial tuberosity. The procedure stayed within the periosteal tube without opening the anterior compartment. Coronal plane deformity correction was achieved by manipulating the osteotomy fragments by the half pins, which were locked to a monolateral external fixator (Dyna EXTOR(SM) II or (M) II; BK MEDITECH, Seoul, Korea) originally designed for fixation of the adult fore-

Table 1. Demographics

Patient number	Sex	Underlying disease	Side	Age at operation, yrs	Deformity
1	F	Hypophosphatemic rickets	Rt.	4.7	Varus
			Lt.	4.7	Varus
2	M	Blount's Disease	Rt.	3.7	Varus
			Lt.	3.7	Varus
3	M	Pseudoachondroplasia	Rt.	8.3	Varus
			Lt.	8.3	Varus
4	M	Multiple epiphyseal dysplasia	Rt.	8.8	Varus
			Lt.	8.8	Varus
5	F	Metaphyseal dysplasia	Rt.	4.3	Varus
			Lt.	4.8	Varus
6	M	Pseudoachondroplasia	Rt.	4.4	Varus
			Lt.	4.4	Varus
			Rt.	8.8	Varus
			Lt.	8.8	Varus
7	M	Hypophosphatemic rickets	Rt.	6.0	Varus
			Lt.	6.2	Varus
8	F	Mucopolysaccharidosis	Rt.	6.3	Valgus
			Lt.	6.3	Valgus

R t., right; Lt., left

arm or humerus. Sagittal and rotational deformity were not corrected. Intraoperative assessment of the deformity correction was done by a straight-line test using a metal rod so that it passed through the centre of the femoral head, knee and ankle joints. Further fixation was applied using cross pinning with Kirschner-wire(s) in 15 cases. One Kirschner-wire was inserted in seven cases and two in eight cases. The wire tip was buried under the skin.

Weight bearing was encouraged at four weeks postoperatively. The external fixator was removed under sedation when full weight bearing was possible at the office. The Kirschner-wires, if present, were removed later as a separate procedure or in combination with other procedure(s) under general anaesthesia. The external fixator could be removed earlier due to cross pin.

Results

The amount of correction of the MPTA averaged 16° (SD 6°; 10° to 29°) in varus tibiae and 16° (SD 2°; 14° to 17°) in valgus tibiae. Preoperative mean MPTA was 73° (SD 4°; 66° to 78°) in varus tibiae and 104° (SD 1°; 103° to 105°) in valgus tibiae. They were corrected to 90° (SD 3°; 85° to 96°) in varus tibiae ($p < 0.05$) and 89° (SD 1°; 88° to 89°) in valgus tibiae immediately postoperatively (Fig. 1). In all, 15 of 17 cases (88.3 %) achieved postoperative MPTA within the normal range (85° to 90°).¹³

The amount of mean correction of MDA was 18.5° (SD 7°; 7° to 29°) in varus tibiae and 26.5° (SD 1°; 26° to 27°) in valgus tibiae. Preoperative mean MDA was 19° (SD 5°; 11° to 24°) in varus tibiae and -25° (SD 2°; -22° to -24°) in valgus tibiae. They were corrected to 0° (SD 4°; -6° to 7°) in varus tibiae ($p < 0.05$) and 2° (SD 1°; 1° to 3°) in valgus tibiae immediately postoperatively.

When full weight bearing became possible at two months postoperatively, there was no loss of correction. The mean MPTA was 89° (SD 2°; 86° to 95°) in varus tibiae and 90° (SD 2°; 87° to 90°) in valgus tibiae ($p > 0.05$) and the mean MDA was 1° (SD 3°; -6° to 7°) in varus tibiae and 3° (SD 1°; 3° to 4°) in valgus tibiae ($p > 0.05$).

PPTA was not changed significantly by the osteotomy. Preoperative mean PPTA was 83° (SD 3°; 75° to 88°) and immediate postoperative mean PPTA was 84° (SD 4°; 75° to 89°) ($p > 0.05$). When full weight bearing became possible at two months postoperatively, PPTA did not change significantly, remaining as an mean of 84° (SD 4°; 74° to 90°) ($p > 0.05$).

Weight bearing was encouraged at one month postoperatively, but full weight bearing was possible at an mean of 1.7 months (1 to 3.0). External fixator was removed at an mean of 2.0 months postoperatively (1 to 3.0). Cross pin was removed at an mean of 4.7 months (1 to 12) under general anaesthesia in all patients.

No neurological or vascular complications developed immediately postoperatively or during the follow-up. There was no osteotomy site fracture, pin tract infection or growth plate injury.

Three patients had recurrent deformity because of underlying pathological conditions; two had pseudoachondroplasia and one mucopolysaccharidosis. One of them was treated using the same procedure 4.4 years later and the other two had transphyseal screw hemiepiphysiodesis or hemiepiphyseal stapling at 4.1 years and 1.0 year postoperatively, respectively.

Illustrative case

A six-year-old boy with hypophosphatemic rickets presented with severe bilateral genu varum deformity. By the proximal tibial osteotomy fixed with monolateral fixator, the MPTA was corrected from 78° and 77° to 91° and 89° in the right and left tibia, respectively. The MDA was also corrected, from 11° and 13° to 0° and 1°, respectively. Tension band plating was applied to the lateral aspect of both distal femurs to gradually correct the distal femoral varus deformity. The PPTA remained the same. Two weeks postoperatively, the patient could bear weight. The external fixator was removed at two months postoperatively and the cross pin at four months postoperatively. The hemiepiphyseal tension band plates were removed at one year postoperatively when a neutral knee alignment was achieved (Fig. 2).

Discussion

This study showed that a small monolateral external fixator was useful for the proximal tibia coronal plane angular deformity correction in small children. Other surgical options in this setting have their own advantages and limitations; these are asymmetric physeal suppression including partial physeal ablation,⁵ physeal stapling,¹⁶ tension band plating^{6,17} and percutaneous hemiepiphysiodesis using transphyseal screw.¹⁸ Asymmetric physeal suppression had an advantage of being a less invasive procedure with fewer complications.^{5,6} There are reports on successful correction of the proximal tibia angular deformity.^{5,6,16,17} But in small children with genetic or metabolic disorders whose epiphysis did not ossify enough, installation of such a device could be difficult or impossible. In children growing slowly because of underlying systemic disease, hemiepiphysiodesis takes longer for angular deformity correction, with a higher risk of physeal arrest, or it may not correct it efficiently.^{6,7} If permanent physeal arrest occurs in small children, the sequelae could be more serious than in teenagers.

Gradual correction using distraction osteogenesis with an external fixator has advantages of multi-planar defor-

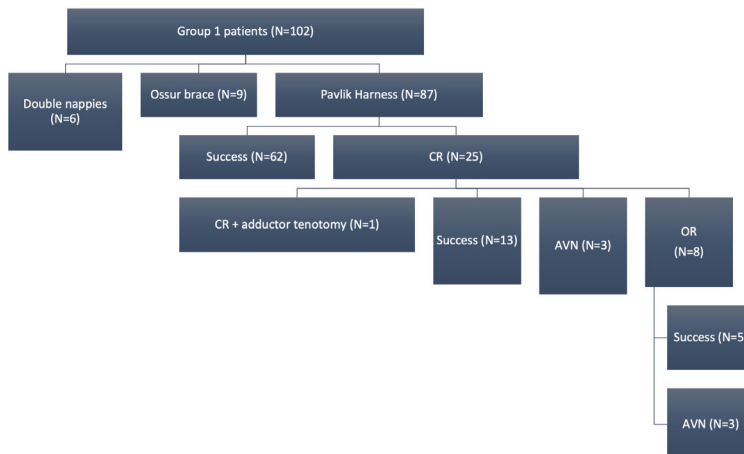


Fig. 1 Changes of medial proximal tibia angle (MPTA).

mity correction, decreased risk for neurovascular injury and early weight bearing and movement.^{2,8} However, in our series, a ring fixator would be too bulky to apply in the cohort of our series.

Acute correction with internal fixation has been widely used in correction of proximal tibial deformity in small children and successful correction has been reported.^{3,4} However, some studies reported inaccurate correction and malunion. Aly¹⁹ reported that only 67% to 75% of cases achieved accurate correction, which was within 5° of normal value (MPTA 87°), by acute correction with Kirschner-wire cross pinning in children of two to four years of age. Applying the same criterion to our study cohort, 88% of cases achieved accurate correction. Although three patients had recurrent deformity during follow-up, it was attributed to the underlying pathology rather than the surgery itself.

Acute correction with a monolateral external fixator can provide accurate correction because it is adjustable throughout the operation. It also provides stable fixation so that small children can bear full weight in the early postoperative period, and no loss of correction was observed in our patients. Small monolateral external fixators designed for the adult forearm bones or humerus were suitable for the fixation of short tibiae in the small children of our series. Compared with hemiepiphyseodesis, this procedure does not run a risk of physeal injury if the osteotomy was made distal to the tibial tuberosity and the half pins were inserted away from the physes, especially at the tibial tuberosity. Price et al²⁰ reported an excellent result of proximal tibia osteotomy fixed with a monolateral external fixator in the surgical treatment of tibia vara. Their study population ranged from small children to adolescents. Adolescent patients may be or could

better be managed using other surgical options, such as asymmetric physeal suppression, gradual correction using an external fixator or osteotomy fixed with plate-and-screw. However, for short tibiae in small children as in our series, the monolateral external fixator of appropriate size may be the fixation of choice.

Acute correction with a monolateral external fixator could be adjusted postoperatively. However, we gave up this chance by combining cross pinning, because, first, the small monolateral external fixator provides only limited stability of fixation, especially when a single half pin was applied to the proximal fragment; second, the cross pinning would allow earlier external fixator removal; and third, the monolateral fixator used in our series was too simple to provide versatile postoperative additional deformity correction.

Nerve injury is the most important complication to be avoided during acute correction of proximal tibia angular deformity. The prophylactic peroneal nerve decompression is an essential technique to avoid nerve injury secondary to acute correction of the valgus deformity.²¹ Moreover, the proximal fragment of the fibular osteotomy usually moves medially after correction of the varus deformity of the tibia, especially when a large correction is achieved.²² This may result in traction and compression of the peroneal nerve and subsequent neurologic complication.^{23,24} In a study of proximal tibial osteotomy fixed with a monolateral dynamic external fixator in Blount's disease, no prophylactic peroneal-nerve decompression was done, and two of 25 patients developed postoperative neuropraxia manifesting as a transient loss of the extensor hallucis longus function.²⁰ In our study, all patients underwent prophylactic peroneal-nerve decompression in varus osteotomy case, and no peroneal-nerve palsy occurred, sug-

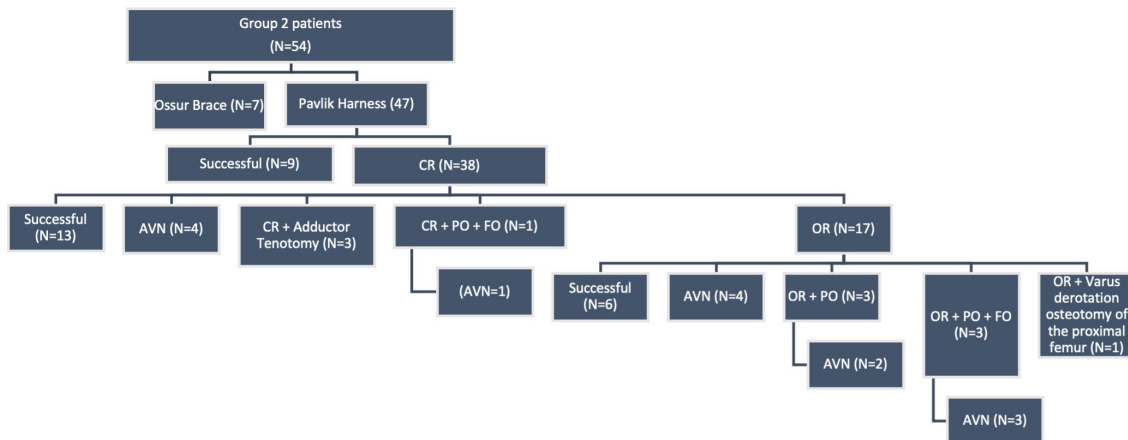


Fig. 2 a) A six-year-old boy with hypophosphatemic rickets; b) proximal tibial varus deformity was corrected by osteotomy fixed with a monolateral external fixator and cross pinning, combined with fibular osteotomy and prophylactic common peroneal nerve decompression. Tension band plates were applied to the lateral distal femoral physis; c) a perfect lower limb alignment was achieved in one year.

gesting that prophylactic peroneal-nerve decompression is effective. We believe that prophylactic peroneal-nerve decompression is warranted in acute varus deformity correction.

Compartment syndrome is one of the most serious potential complications of acute correction of the proximal tibia angular deformity, and prophylactic fasciotomy is recommended.²⁵ However, in our series, the proximal tibial osteotomy was performed within the subperiosteal space without damaging the anterior compartment which was possible thanks to the thick periosteum. No prophylactic fasciotomy was done, and no compartment syndrome developed in this series.

This study has several limitations. First, because there was no control group that was treated with other surgical procedures, we could not compare our surgical outcome with other procedures. As we narrowed the inclusion criteria down to only small children, the patients who could be treated with other procedures, such as guided growth or acute correction with internal fixation, were not included. Second, we could not apply the exact same procedure to every patient uniformly. Some tibiae were fixed with adjunct Kirschner-wire cross pinning, but some were not. The proximal fragment was fixed with one half pin in some tibiae, but two half pins in others. However, since the size of tibia was diverse by age, sex and underlying disease, our study reflects the reality of the clinical situation. Third, our study group consisted of patients with various diseases. Because of the rarity of small patients who need surgery

for proximal tibial varus/valgus deformity, it was almost impossible to collect patients with the same condition.

Nevertheless, we conclude that proximal tibia osteotomy fixed with a small monolateral external fixator is an effective surgical option for correction of coronal plane angular deformity of the proximal tibia in small children, especially those associated with genetic or metabolic skeletal disorder, providing accurate correction and stable fixation. Concomitant fibular osteotomy and prophylactic common peroneal-nerve decompression is warranted to achieve easy angular correction and to prevent peroneal-nerve injury.

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COMPLIANCE WITH ETHICAL STANDARDS

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ETHICAL STATEMENT

Ethical approval: The data in this retrospective study was obtained after getting approval from our institutional review board. All procedures performed in

studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: The informed consent was waived by the institutional review board due to the retrospective nature of the study.

ICMJE CONFLICT OF INTEREST STATEMENT

None declared.

AUTHOR CONTRIBUTIONS

CML: Acquisition, analysis and interpretation of data; Drafting the manuscript.

CHS: Design of the work; Interpretation of data; Critical review of the manuscript.

WJY: Conception of the work; Interpretation of data; Critical review of the manuscript.

TJC: Conception of the work; Analysis and interpretation of data; Drafting and critical review of the manuscript.

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