Medicine®

Salter-Harris type II fractures of the distal tibia
Residual postreduction displacement and outcomes—a STROBE compliant study

Adam Margalit, MD, Kranti V. Peddada, MD, Alexandra M. Dunham, MD, Craig M. Remenapp, MS,
R. Jay Lee, MD*

Abstract

We assessed factors associated with premature physeal closure (PPC) and outcomes after closed reduction of Salter-Harris type II (SH-II) fractures of the distal tibia. We reviewed patients with SH-II fractures of the distal tibia treated at our center from 2010 to 2015 with closed reduction and a non-weightbearing long-leg cast. Patients were categorized by immediate postreduction displacement: minimal, <2 mm; moderate, 2 to 4 mm; or severe, >4 mm. Demographic data, radiographic data, and Lower Extremity Functional Scale (LEFS) scores were recorded.

Fifty-nine patients (27 girls, 31 right ankles, 26 concomitant fibula fractures) were included, with a mean (±SD) age at injury of 12.0 ± 2.2 years. Mean maximum fracture displacements were 6.6 ± 6.5 mm initially, 2.7 ± 2.0 mm postreduction, and 0.4 ± 0.7 mm at final follow-up. After reduction, displacement was minimal in 23 patients, moderate in 21, and severe in 15. Fourteen patients developed PPC, with no significant differences between postreduction displacement groups. Patients with high-grade injury mechanisms and/or initial displacement ≥4 mm had 12-fold and 14-fold greater odds, respectively, of PPC. Eighteen patients responded to the LEFS survey (mean 4.0 ± 2.1 years after injury). LEFS scores did not differ significantly between postreduction displacement groups (P = .61).

The PPC rate in this series of SH-II distal tibia fractures was 24% and did not differ by postreduction displacement. Initial fracture displacement and high-grade mechanisms of injury were associated with PPC. LEFS scores did not differ significantly by postreduction displacement.

Level of Evidence: Level IV, case series

Abbreviations: LEFS = Lower Extremity Functional Scale, ORIF = open reduction and internal fixation, PPC = premature physeal closure, SH-II = Salter-Harris type II.

Keywords: distal tibia fracture, nonoperative treatment, postreduction fracture displacement, premature physeal closure, Salter-Harris type II fracture

1. Introduction

Ankle fractures are the second most common cause of physeal injuries in children, second only to distal radius fractures.[1] Closure of the distal tibial physis starts centrally, continues medially, and proceeds laterally.[2] This sequential progression is responsible for the fracture patterns observed in the immature ankle. Salter-Harris type II (SH-II) injuries are the most frequent, accounting for up to 40% of all distal tibia fractures.[3] The mean age at the time of injury is 12.6 years, and the prevalence of concomitant fibula fractures is 63%.[4]

The distal physis contributes 50% toward longitudinal growth of the tibia, and injuries may result in premature physeal closure (PPC) and angular deformity.[5] Rates of PPC after SH-II injuries have been reported as 2% to 43%.[4,6–8] Risk factors for PPC may include mechanism of injury, initial degree of fracture displacement, degree of postreduction residual displacement, patient age and remaining growth potential, and treatment type.[6,9] The acceptable degree of fracture displacement has not been established.[3,4,6,9]

To reduce the rate of PPC, Barmada et al[6] recommended open reduction and internal fixation (ORIF) for patients with a postreduction residual gap (defined as >3 mm) by removal of

entrapped periosteum. They showed that patients with such a gap had a 3.5-fold greater risk of developing PPC. However, Russo et al[4] demonstrated that although ORIF and the removal of interposed tissue may improve joint alignment, and possibly subsequent function, it does not reduce the incidence of PPC and may actually increase the need for subsequent surgery compared with closed reduction. They recommended that most patients with SH-II fractures be treated with closed reduction.

The purpose of this study was to identify PPC risk factors and to assess functional outcomes in nonoperatively treated patients with SH-II distal tibia fractures with varying degrees of postreduction displacement. We hypothesized that there would be no significant differences in PPC rates or functional outcomes in patients by degree of postreduction displacement. We hypothesized that patients with high-energy mechanisms of injury and those with larger initial displacements would have higher rates of PPC.

2. Methods

2.1. Study design, setting, and participants

This retrospective study was approved by our institutional review board (approval no. IRB00079284) in November 2015. We included patients aged 6 to 16 years with SH-II distal tibia fractures who presented to 1 of 5 pediatric orthopedists at our large, academic pediatric specialty hospital for initial treatment between January 2010 and June 2015.

We identified patients by using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM), codes 823.20, 823.22, 823.80, 823.82, and 824.8. We included patients diagnosed with SH-II distal tibia fractures who also had anteroposterior, lateral, and mortise radiographs available at initial presentation, postreduction, and final follow-up (at least 3 months). Patient age, sex, length of follow-up, side of injury, presence of a concomitant fibula fracture, mechanism of injury, number of reduction attempts, PPC status, and amounts of initial and postreduction displacement were recorded. Fractures were further classified using the Dias-Tachdjian modification of the Lauge-Hansen classification of ankle fractures in children.[10] Any clinically relevant complications or subsequent surgical procedures, such as epiphysiodesis, were noted. We excluded patients with open fractures, pathological fractures, fractures with neurovascular compromise, and distal tibia fractures with an epiphyseal component, as well as those who presented >7 days after initial injury. Patients were categorized into 3 groups on the basis of postreduction residual displacement (minimal, <2 mm; moderate, 2–4 mm; and severe, >4 mm). Displacement was measured as the largest distance between the metaphysis and epiphysis or the fracture fragments at the level of the physis on any of the 3 radiographic views (Fig. 1).

At our institution, most acutely displaced SH-II fractures are treated nonoperatively with closed reduction in the emergency department. Minimally displaced SH-II fractures were often treated without reduction. Patients were treated with a long-leg cast for 4 to 6 weeks without weightbearing and transitioned to weightbearing as tolerated for 2 to 3 weeks in a short-leg cast, in a walking boot, or unsupported, depending on surgeon preference. PPC was determined by follow-up radiography and/or computed tomography.

To assess functional outcomes at final follow-up, we contacted patients and/or family members via telephone. After providing
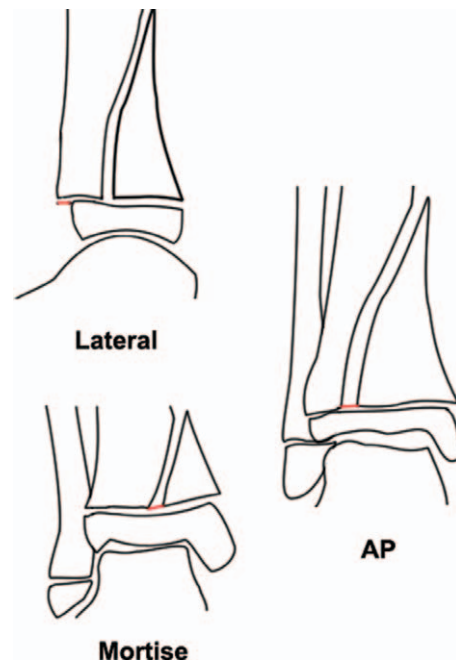

Figure 1. Depiction of how initial and residual postreduction fracture displacement was measured. The largest distances (red lines) between the metaphysis and epiphysis or the fracture fragments at the level of the physis were chosen in the anteroposterior (AP), lateral, and mortise views.

verbal consent, the patient or the patient's legal guardian (for patients aged <18 years) completed the Lower Extremity Functional Scale (LEFS) questionnaire (Fig. 2). The LEFS questionnaire was created in 1999 and is used to evaluate the function of patients with musculoskeletal conditions of the lower extremity.[11] It consists of 20 items, each rated on a 5-point scale (0–4). The total scores range from 0 (lowest function) to 80 (highest function).

2.2. Statistical analysis

We used descriptive statistics for demographic information and 1-way analysis of variance and chi-squared tests of independence to assess differences in continuous and dichotomous variables, respectively, among the 3 aforementioned groups. Chi-squared or Fisher exact tests were used to assess differences in dichotomous variables between patients with PPC and those without PPC at final follow-up, which was further evaluated with logistic regression. All analyses were performed with SPSS, version 23.0, software (SPSS, Inc., Chicago, IL). Alpha level was set at 0.05.

3. Results

3.1. Patient characteristics

We identified 645 patients using the aforementioned *ICD-9-CM* codes. Of those, 114 (18%) were categorized as having distal tibia SH-II fractures. Fifty-five patients were excluded because of a lack of radiographs and/or follow-up data. Fifty-nine patients (27 girls) met our inclusion criteria. The mean age at injury was 12 years (range, 6.6–16) with a mean follow-up of 4.8 months (range, 3.1–33).

Today, *do you* or *would you* have any difficulty at all with:

Question Number	Activities	Extreme difficulty or unable to perform activity	Quite a bit of difficulty	Moderate difficulty	A little bit of difficulty	No difficulty
1	Any of your usual work, housework or school activities.	0	1	2	3	4
2	Your usual hobbies, recreational or sporting activities.	0	1	2	3	4
3	Getting into or out of the bath.	0	1	2	3	4
4	Walking between rooms.	0	1	2	3	4
5	Putting on your shoes or socks.	0	1	2	3	4
6	Squatting.	0	1	2	3	4
7	Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
8	Performing light activities around your home.	0	1	2	3	4
9	Performing heavy activities around your home.	0	1	2	3	4
10	Getting into or out of a car.	0	1	2	3	4
11	Walking 2 blocks.	0	1	2	3	4
12	Walking a mile.	0	1	2	3	4
13	Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
14	Standing for 1 hour.	0	1	2	3	4
15	Sitting for 1 hour.	0	1	2	3	4
16	Running on even ground.	0	1	2	3	4
17	Running on uneven ground.	0	1	2	3	4
18	Making sharp turns while running fast.	0	1	2	3	4
19	Hopping.	0	1	2	3	4
20	Rolling over in bed.	0	1	2	3	4

Minimum Level of Detectable Change (90% Confidence): 9 points SCORE: _____/ 80

Figure 2. Lower Extremity Functional Scale (LEFS) questionnaire, which was created in 1999 and is used to evaluate the functional status of patients with musculoskeletal conditions of the lower extremity. It consists of 20 items each rated on a 5-point scale (0–4). Scores range from 0 (lowest function) to 80 (highest function).

The most common cause of fracture was sports-related injuries (n=36), followed by nonspecific falls (n=15), motor vehicle accidents (n=5), and indeterminate causes (n=3). Sports-related injuries occurred during football (n=8); soccer (n=5); roller skating, running, and wrestling (n=4 each); riding an electric scooter and skateboarding (n=3 each); basketball (n=2); and ice skating, dancing, and softball (n=1 each). Injuries were further categorized as contact (n=18) or noncontact (n=18) sport injuries. Nonspecific falls were further categorized as falls from <1.5 m (n=13) or ≥1.5 m (n=5). Injury mechanisms were considered low-grade (n=30) if they were noncontact injuries, falls from <1.5 m, or from indeterminate causes, and they were considered high-grade (n=29) if they were contact injuries, falls from ≥1.5 m, or from a motor vehicle accident.

There were 31 right-sided and 28 left-sided fractures, with 26 concomitant fibula fractures. The most common fracture types were supination–external rotation fractures (n=28), followed by supination–plantar flexion fractures (n=18), and pronation-eversion–external rotation fractures (n=13) (Fig. 3).

3.2. Postreduction displacement

The mean maximum initial displacement was 6.6 mm (range, 0.4–29), and the mean number of reduction attempts was 1 (range, 0–2). The mean maximum residual gap was 2.7 mm (range, 0–7) after reduction and 0.4 mm (range, 0–2) at final follow-up. Twenty-three patients (39%) had minimal displacement, 21 (36%) had moderate displacement, and 15 (25%) had severe displacement immediately after reduction (Table 1). There were no significant differences in patient age, sex, concomitant fibula fractures, PPC, high-grade vs low-grade mechanism of injury, or Dias-Tachdjian classification by degree of postreduc-
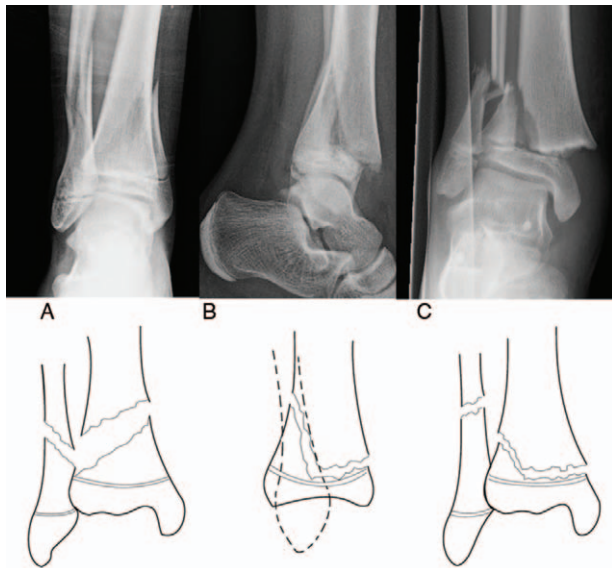
Figure 3. Dias-Tachdjian modification of the Lauge-Hansen classification of ankle fractures in children showing Salter-Harris type II fractures caused by A) supination–external rotation, (B) supination–plantar flexion, and (C) pronation-eversion–external rotation mechanisms.

tion displacement (Table 1). Patients with severe postreduction displacement underwent more closed reduction attempts and had larger initial fracture displacement than patients with minimal or moderate displacement.

3.3. Premature physeal closure

Fourteen patients developed PPC. There was no significant difference in the rates of PPC among postreduction displacement groups ($P = .23$); 4 patients each had minimal and moderate displacement, and 6 patients had severe displacement. Five of the 14 patients with PPC underwent ipsilateral and contralateral

epiphysiodesis because of growth arrest of the fractured limb (Fig. 4). The other 9 patients had <1.5 years of remaining growth and did not develop angular deformities.

At final follow-up, we examined the associations of patient and clinical factors with PPC (Table 2). Only mechanism of injury (high-grade vs low-grade) (χ^2 [1, n=59]=9.82; $P = .002$) and initial maximum displacement (χ^2 [1, n=59]=10.77; $P = .001$) were significantly associated with the development of PPC (Table 2). Similarly, on univariate logistic regression, mechanism of injury and initial maximum displacement were significantly associated with PPC at final follow-up (Table 3). On multivariate logistic regression, only high-grade mechanism of injury and severe initial maximum displacement were significantly associated with PPC (Table 3). Patients with a high-grade mechanism of injury and severe initial maximum displacement had 12 times and 14 times greater odds, respectively, of developing PPC. Results of the Hosmer-Lemeshow goodness-of-fit test were not significant (χ^2 (7)=10.0; $P = .19$), indicating that the model was a good fit. The model explained 51% (Nagelkerke R^2) of the variance in PPC and correctly classified 85% of cases. Sensitivity was 79%, specificity was 89%, positive predictive value was 69%, and negative predictive value was 93%.

3.4. Functional outcomes

Eighteen patients completed the LEFS survey (administered at a mean 4.0 ± 2.1 years after injury). There was no significant difference in LEFS scores between postreduction displacement groups ($P = .61$). Mean LEFS scores were 76 ± 6.0 for 9 patients with minimal displacement, 80 ± 5.0 for 4 patients with moderate displacement, and 76 ± 8.4 for 5 patients with severe displacement (Table 1, Fig. 5). Three of the 18 respondents had PPC (2 patients with minimal and 1 with severe postreduction displacement). Only 1 patient with minimal postreduction displacement underwent epiphysiodesis and had a LEFS score of 73 at 3 years after injury; the other 2 patients had LEFS scores of 80 at 2.5 and 3 years after initial injury and did not require surgery.

Table 1

Demographic and clinical parameters in 59 patients with Salter-Harris type II fractures of the distal tibia by degree of residual postreduction displacement.

Parameter	Degree of postreduction displacement[*]						P
	Minimal (n=23)		Moderate (n=21)		Severe (n=15)		
	Mean ± SD	n (%)	Mean ± SD	n (%)	Mean ± SD	n (%)	
Age, yrs	12±2.3		13±1.8		12±2.3		.10
Female sex		9 (39)		8 (38)		10 (67)	.17
Concomitant fibula fracture		10 (44)		8 (38)		8 (53)	.66
Initial fracture displacement (mm)	4.0±4.6		7.9±8.1		9.2±4.8		.04
Reduction attempts	0 (0–1)[†]		1 (0–2)[†]		1 (0–2)[†]		.002
Premature physeal closure		4 (17)		4 (19)		6 (40)	.23
Injury characteristics							
High-grade mechanism		9 (39)		12 (57)		8 (53)	.46
Supination–external rotation		14 (61)		8 (38)		6 (40)	.26
Supination–plantar flexion		5 (22)		9 (43)		4 (27)	.29
Pronation-eversion–external rotation		4 (17)		4 (19)		5 (33)	.47
LEFS score[‡]	76±6.0		80±5.0		76±8.4		.61

LEFS, Lower Extremity Functional Scale; SD, standard deviation.

[*] Minimal, <2 mm; moderate, 2–4 mm; severe, >4 mm.

[†] Expressed as mean (range).

[‡] N (%) of patients completing LEFS survey was 9 (39) in minimal group, 4 (19) in moderate group, and 5 (33) in severe group.

Figure 4. Radiographs of a 13-year-old boy with a Salter-Harris type II distal tibia fracture after a sports-related contact injury (A) [anteroposterior view (top) and lateral view (bottom)], who underwent closed reduction and long-leg casting (B) [anteroposterior view (top) and lateral view (bottom)]. He healed well radiographically 3 months later (C) [anteroposterior view (top) and lateral view (bottom)]. However, follow-up CT scan demonstrated physeal bar formation >50% (D) [coronal view (top) and axial view (bottom)] with a limb length discrepancy of 1 cm 1 year later on standing radiographs (E). He underwent bilateral epiphysiodesis to prevent further limb length discrepancy (F) (fluoroscopy view).

4. Discussion

This study shows the results of nonoperative treatment of SH-II distal tibia fractures. PPC was evident in nearly one-fourth of our patient population. PPC was associated with the degree of maximum displacement at time of injury (≥4 mm) and high-grade injury mechanisms. There was no difference in the rate of PPC by immediate postreduction fracture displacement. Theoretically, surgical intervention may restore anatomic joint alignment and therefore function; however, we found adequate bone remodeling radiographically and no differences in functional outcomes by degree of postreduction displacement.

SH-II distal tibia fractures account for 30% to 40% of physeal ankle fractures in children.[3,9] The reported mean age at injury ranges from 11.6 to 12.6 years[3,4,6,8,9,12,13], with concomitant fibula fracture occurring in 22% to 64% of patients.[3,4,13] Although historical data from Dugan et al[7] suggest that SH-II

Table 2

Associations of patient and clinical factors with PPC at final follow-up in 59 patients with distal tibia Salter-Harris type II fractures.

	N (%)			
Parameter	**Patients without PPC (n=45)**	**Patients with PPC (n=14)**	**χ^2 (df)**	**P**
Sex				
Female	21 (47)	6 (43)	0.06 (1)	.80[*]
Male	24 (53)	8 (57)		
Concomitant fibula fracture				
No	28 (62)	5 (36)	3.04 (1)	.08[*]
Yes	17 (38)	9 (64)		
Injury mechanism				
Low-grade	28 (62)	2 (14)	9.82 (1)	.002[*]
High-grade	17 (38)	12 (86)		
Dias-Tachdjian classification				
Supination–external rotation	22 (49)	6 (43)	0.46 (2)	.79[†]
Supination–plantar flexion	14 (31)	4 (29)		
Pronation-eversion–external rotation	9 (20)	4 (29)		
Reduction attempts				
0 or 1	40 (89)	11 (79)	0.97 (1)	.33[†]
2	5 (11)	3 (21)		
Initial maximum displacement				
<4 mm	29 (64)	2 (14)	10.8 (1)	.001[*]
≥4 mm	16 (36)	12 (86)		
Postreduction maximum displacement				
<4 mm	36 (80)	8 (57)	2.94 (1)	.09[†]
≥4 mm	9 (20)	6 (43)		

DF = degrees of freedom, PPC = premature physeal closure.

[*] From chi-squared analysis.

[†] From Fisher exact test (2-sided).

Table 3

Odds of patient and clinical factors predicting premature physeal closure in 59 patients with distal tibia Salter-Harris type II fractures.

Parameter	Univariate model		Multivariate model	
	OR (95% CI)	P	OR (95% CI)	P
Sex				
Female		Referent		
Male	1.2 (0.35–3.9)	0.80	0.56 (0.07–4.3)	.58
Associated fibula fracture				
No		Referent		
Yes	3.0 (0.85–10)	0.09	1.8 (0.23–13)	.58
Injury mechanism				
Low-grade		Referent		
High-grade	9.9 (2.0–50)	0.005	12 (1.6–93)	.015
Dias-Tachdjian classification				
Supination–external rotation		Referent		
Supination–plantar flexion	1.1 (0.25–4.4)	0.95	0.78 (0.12–5.2)	.79
Pronation-eversion–external rotation	1.6 (0.37–7.2)	0.52	0.68 (0.91–5.1)	.71
Reduction attempts				
0 or 1		Referent		
2	2.2 (0.45–11)	0.33	2.0 (0.17–23)	.59
Initial maximum displacement				
<4 mm		Referent		
≥4 mm	24 (2.8–197)	0.004	14 (1.1–171)	.04
Postreduction maximum displacement				
<4 mm		Referent		
≥4 mm	3.0 (0.83–11)	0.09	0.91 (0.12–7.1)	.93

CI = confidence interval, OR = odds ratio.

distal tibia fractures are associated with a low rate of PPC (2% to 5%), more recent studies indicate much higher rates, ranging from 17% to 43%.[3,4,6,8,9,12,13] SH-II fractures of the distal tibia should be regarded as high-risk fractures, or at least as fractures with unpredictable sequelae. In 1978, Spiegel et al[3] described SH-II fractures of the distal tibia as unpredictable because fractures that showed little or no displacement developed complications as readily as those that were considerably displaced. Our results are in concordance with the existing literature.

Of the 14 patients who developed PPC, 5 underwent epiphysiodesis because of growth arrest of the fractured limb. Severe initial fracture displacement was significantly associated with PPC (OR = 14). Similarly, Leary et al[9] showed that each

Figure 5. Radiographs of a 9-year-old boy with a 7.4-mm anteriorly displaced Salter-Harris type II distal tibia fracture (A) immediately after closed reduction and application of a long-leg cast, and (B) 5 months later. This patient had a perfect Lower Extremity Functional Scale score of 80 two years after his injury.

millimeter of initial displacement was associated with increased risk of PPC by a factor of 1.2 (P < .001), whereas other studies have not detected an association between PPC and degree of initial fracture displacement.[4,6,8] There was no significant difference in the degree of displacement immediately after reduction for the patients who eventually developed PPC. Similarly, Russo et al[4] reported a PPC rate in operatively treated SH-II distal tibia fractures of 43%, with no significant differences in PPC rates among subgroups by degree of displacement (2 mm, 2–4 mm, or >4 mm). Other studies have similarly found no significant association between degree of postreduction fracture displacement and PPC,[13] whereas others show that the degree of postreduction displacement is associated with PPC.[6,8,9,12,14] Although a greater proportion of patients with severe postreduction displacement developed PPC (40%), this difference was not significant compared with the other displacement groups (minimal, 17%; moderate, 19%, P = .23).

A more important risk factor for PPC may be the fracture pattern or mechanism of injury. Park et al[13] showed an increased risk of PPC in pronation-abduction injuries (OR = 4.0) and pronation–external rotation injuries (OR = 6.6) compared with supination–external rotation injuries. Other studies have found no significant difference in PPC by mechanism of injury when comparing pronation with supination injuries.[4,8] We found no difference in PPC based on the Dias-Tachdjian classification. However, patients who had high-grade injury mechanisms had a significantly higher rate of PPC compared with those with low-grade mechanisms.

Park et al[13] and Russo et al[4] found no difference in PPC rates among patients with similar degrees of postreduction displacement treated operatively vs nonoperatively. Regardless of how well the reduction corrects the deformity, patients may still develop PPC. It is plausible that compression forces during the initial trauma cause a physeal crush injury leading to PPC.
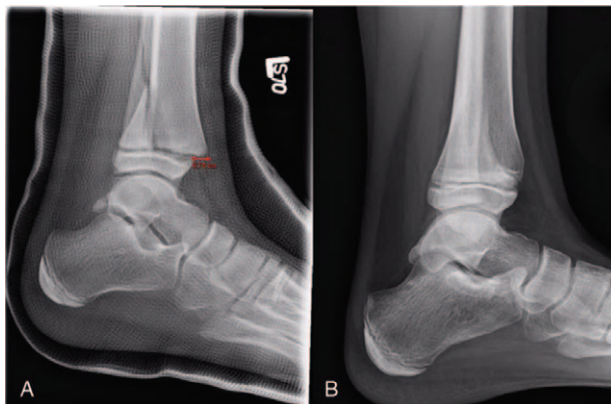
Although Russo et al[4] recommended against surgery to prevent PPC, they suggested that surgery helps improve function by creating more anatomical joint alignment. However, we found no differences in LEFS scores at final follow-up based on degree of immediate postreduction displacement.

Our study is limited by several factors, most notably the small sample size. The number of respondents to the outcome questionnaire was limited, and our analysis is underpowered. However, our data are from a center that typically treats distal tibia fractures nonoperatively, which makes our series unique. A multicenter prospective study would help achieve larger sample size in the future. Prospective studies are needed to determine long-term outcomes after nonoperative treatment of SH-II distal tibia fractures. Such studies would help surgeons decide on the basis of fracture pattern and/or postreduction measurements whether ORIF produces better outcomes, or whether closed reduction with close observation for possible limb correction procedures is optimal.

The use of the LEFS questionnaire is also limited. Given the mean patient age at injury (12 ± 2 years) and the mean time elapsed since injury (4.0 ± 2.1 years), it is challenging for patients to make judgments about prior versus current functioning because of recall bias. The LEFS survey has been administered via telephone to assess lower extremity function[15] but requires further validation for our patient population. Despite these limitations, our results provide valuable information about this fracture type.

In conclusion, we recommend an initial nonoperative treatment approach to SH-II distal tibia fractures. The PPC rate in this series of SH-II distal tibia fractures was 24% and did not differ by severity of postreduction displacement. Initial fracture displacement ≥ 4 mm and high-grade mechanisms of injury were associated with PPC. Providers should be aware of these risk factors when educating patients about potential sequelae after this injury.

Acknowledgments

Author contributions

Study design: Adam Margalit, Kranti V. Peddada, Alexandra M. Dunham, Craig M. Remenapp, and R. Jay Lee

Performed measurements: Adam Margalit, Kranti V. Peddada, Alexandra M. Dunham, Craig M. Remenapp, and R. Jay Lee
Statistical analysis: Adam Margalit
Manuscript preparation: Adam Margalit, Kranti V. Peddada, and R. Jay Lee
Writing – review & editing: Adam Margalit, Kranti Peddada, Alexandra Dunham, Craig Remenapp.
R. Jay Lee orcid: 0000-0002-4692-9531.

References

[1] Peterson CA, Peterson HA. Analysis of the incidence of injuries to the epiphyseal growth plate. J Trauma 1972;12:275–81.

[2] Rosenbaum AJ, DiPreta JA, Uhl RL. Review of distal tibial epiphyseal transitional fractures. Orthopedics 2012;35:1046–9.

[3] Spiegel PG, Cooperman DR, Laros GS. Epiphyseal fractures of the distal ends of the tibia and fibula. A retrospective study of two hundred and thirty-seven cases in children. J Bone Joint Surg Am 1978;60:1046–50.

[4] Russo F, Moor MA, Mubarak SJ, et al. Salter-Harris II fractures of the distal tibia: does surgical management reduce the risk of premature physeal closure? J Pediatr Orthop 2013;33:524–9.

[5] Karrholm J, Hansson LI, Svensson K. Prediction of growth pattern after ankle fractures in children. J Pediatr Orthop 1983;3:319–25.

[6] Barmada A, Gaynor T, Mubarak SJ. Premature physeal closure following distal tibia physeal fractures: a new radiographic predictor. J Pediatr Orthop 2003;23:733–9.

[7] Dugan G, Herndon WA, McGuire R. Distal tibial physeal injuries in children: a different treatment concept. J Orthop Trauma 1987;1:63–7.

[8] Rohmiller MT, Gaynor TP, Pawelek J, et al. Salter-Harris I and II fractures of the distal tibia: does mechanism of injury relate to premature physeal closure? J Pediatr Orthop 2006;26:322–8.

[9] Leary JT, Handling M, Talerico M, et al. Physeal fractures of the distal tibia: predictive factors of premature physeal closure and growth arrest. J Pediatr Orthop 2009;29:356–61.

[10] Dias LS, Tachdjian MO. Physeal injuries of the ankle in children: classification. Clin Orthop Relat Res 1978;136:230–3.

[11] Binkley JM, Stratford PW, Lott SA, et al. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. Phys Ther 1999;79:371–83.

[12] Ozkul B, Saygili MS, Cetinkaya E, et al. Angular deformity development after the distal tibial physeal fractures. Acta Orthop Belg 2016;82:814–20.

[13] Park H, Lee DH, Han SH, et al. What is the best treatment for displaced Salter-Harris II physeal fractures of the distal tibia? Acta Orthop 2018;89:108–12.

[14] Schurz M, Binder H, Platzer P, et al. Physeal injuries of the distal tibia: long-term results in 376 patients. Int Orthop 2010;34:547–52.

[15] Logan DE, Carpino EA, Chiang G, et al. A day-hospital approach to treatment of pediatric complex regional pain syndrome: initial functional outcomes. Clin J Pain 2012;28:766–74.