

The midterm outcomes of ankle Dias-Tachdjian pronation-eversion external rotation physeal fracture in children treated by open reduction internal fixation with one-stage medial-lateral combined incision

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The objective of this study was to report the midterm outcomes and complications of ankle Dias-Tachdjian pronation-eversion external rotation (PEER) physeal fracture in children treated by ORIF with combined medial and lateral incision. A total of 21 children with ankle Dias-Tachdjian PEER physeal fracture underwent open reduction internal fixation treatment with combined medial and lateral incision between January 2015 and October 2017. The lateral distal tibia angle (LDTA) was measured to evaluate angular deformity and the X-rays were taken to evaluate the premature physeal arrest. All patients were followed up for an average time of 20.1 months (ranging from 17 to 25 months). Bone healing was achieved in all cases. American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) score of the patients improved from median 31 (11, 38) preoperation to median 68 (63, 73) postoperation to median score 91 (87, 96) at last follow-up. LDTA of the patients improved from 70.5 ± 4.9 preoperation to 90.0 ± 1.2 postoperation, to measure 90.6 ± 3.7 at last follow-up. The differences were statistically significant ($P < 0.05$). There is no premature

physeal closure, ankle deformity in 19 cases. They could normally exercise and take part in normal sport activities. The remaining two cases had physeal bone bridge and premature physeal closure but could still carry on daily activities and thus were categorized as good. ORIF with one-stage medial-lateral combined incision for ankle Dias-Tachdjian PEER physeal fracture can decrease the rate of premature physeal closure and should be a treatment choice. *J Pediatr Orthop B* 30: 438–442 Copyright © 2020 The Author(s). Published by Wolters Kluwer Health, Inc.

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Introduction

The physeal fracture is a common type of fractures, accounting for 20–30% of all fractures in children. The distal tibial type constitutes one-third of physeal fractures [1] and is primarily induced by falling injuries [2]. The most important complication is premature physeal closure-related limb deformity. Incomplete reduction and multiple closed reductions can increase the risk of premature physeal closure. Around 25% of distal tibial physeal fractures are accompanied by fibular fracture. The stable fibula after reduction is beneficial for the healing of distal tibial physeal injury and can shorten the healing time of tibial physis [3]. The current treatment strategies include expectant treatment, fixation with an external fixator, internal fixation with a locked reconstruction plate in combination

with the Kirschner wire and fixation with the absorbable screw [4,5].

There are several researches that focus on pediatric distal tibial physeal injury, but most of them are based on Salter–Harris classification. It is reported by Rohmiller *et al.* [6] that patients with ABD type injuries developed PPC more higher than patients with other types. The Dias–Tachdjian system is based on the position of the foot and the direction of force at the time of injury with four major patterns: supination–inversion, PEER, supination–plantar flexion and supination–external rotation. In the present study, we discussed the midterm outcomes and complications of combined medial and lateral incision for the treatment of ankle Dias–Tachdjian PEER physeal fracture in children. Fracture healing and complications were also assessed via imaging.

Materials and methods

Study population

Children with ankle fracture treated at our department between January 2015 and October 2017 were enrolled in

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the current study. All subjects met the following criteria: (1) ankle Dias-Tachdjian PEER physeal fracture diagnosed by two experienced pediatric orthopedists reading the film; (2) fracture gap >3 mm under fluoroscopy (measured by a 3-mm scaleplate put beside the tibia) after reductions once or twice under anesthesia and muscle relaxation in OR and (3) aged <15 years old at the time of last follow-up. A total of 21 patients, 12 males and 9 females with an average age of 10.3 ± 1.8 years (6–14 years) were eligible. There were 13 cases of the right foot injury and 8 of the left foot injury; 12 cases were caused by falling injury and 9 cases by road traffic injury.

Surgical procedures

Placed in the supine position, the patient was given general anesthesia and the fracture end was fixed under the fluoroscopy. Lateral and medial longitudinal incisions were successively made, and the skin, subcutaneous tissue and deep fascia were cut to fully expose the fracture ends. The fibular fracture was fixed with the locked reconstruction plate, which was proved rigid under the fluoroscopy and direct vision. An incision was made in the medial tibia to remove the curled periosteum in the fracture (Fig. 1). After anatomical reduction of the distal tibia physis, the fracture was crossly fixed with the Kirschner wire (1.6 mm), which was also rigid under the fluoroscopy. Finally, the wound was rinsed, sutured and dressed. The Kirschner wires were removed 6 weeks after the operation, and the plate was removed after 6–9 months after operation under lower-extremity nerve block anesthesia.

Data collection

Lateral distal tibia angle (LDTA) in the anterior-posterior radiography pre- and postoperation and during the last follow-up were used as the evaluating indicators, which were measured as the angle of the axial line

of the tibia with the tibia-ankle joint line. American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) were recorded before the operation, post-operation and the last follow-up (Table 1). (All AOFAS Questionnaires were filled by patients and their parents together, and preinjury AOFAS was done by the assessment of their parents.)

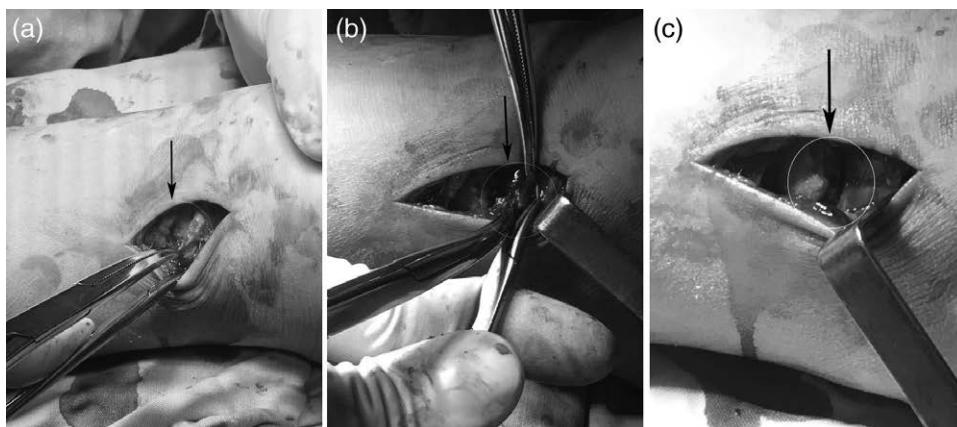
Statistical analysis

SPSS was used for statistical analysis. The AOFAS-AH score was expressed as the median (min, max). The LDTA degree was expressed as the mean \pm SD. All measured data during pre- and postoperation and the last follow-up were compared using the Wilcoxon signed-rank test. $P < 0.05$ was considered statistically different.

Results

All patients were followed up postoperation, with the average follow-up period of 20.1 ± 2.1 months. Bone union was achieved in all 21 cases and no disunion was seen. AOFAS-AH of ankle function above 90 stood for excellent, 75–89 for good, 50–74 for fair and below 50 for poor [5] and was used to evaluate the pain, walking, active movement, ankle joint function, stability and deformity. AOFAS-AH of the patients improved median 31 (11, 38) before the operation to median 68 (63, 73) postoperation, median score 91 (87, 96) at last follow-up. There was a significant difference among the preoperation, postoperative and last follow-up scores ($P < 0.05$). A total of 16 cases were categorized as excellent and 5 cases as good. During the last follow-up, 19 patients reported normal ankle joint ability and no discomfort, whereas the other two patients reported slightly limited activity of the ankle joint. LDTA of the patients improved from 70.5 ± 4.9 before operation to 90.0 ± 1.2 postoperation, measure 90.6 ± 3.7 at last follow-up. The differences between pre- and

Fig. 1

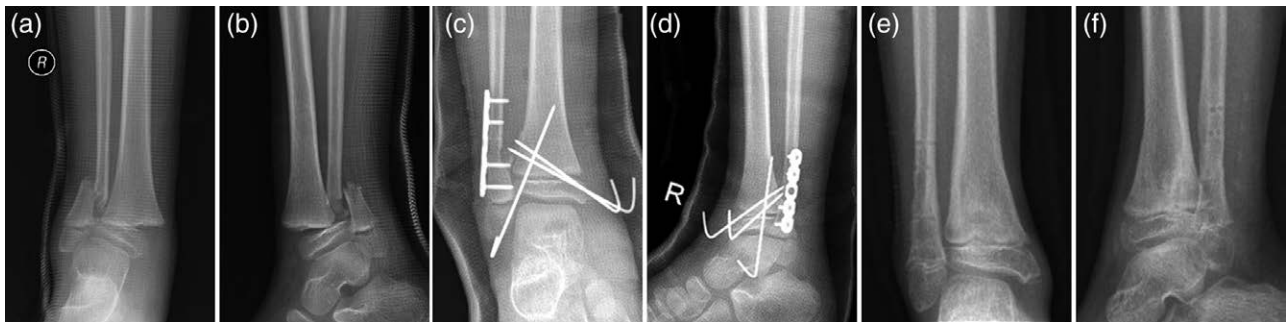


Intraoperative photographs. (a) Periosteum embedded in the fracture end, blocking the reduction; (b) periosteum was removed from the fracture end and (c) fracture end after removing periosteum.

Table 1 General information of selected children

No	Gender	Age/years	Left/right	FU time/month	AOFAS			LDTA		
					PreOP	PostOP	Last FU	PreOP	PostOP	Last FU
1	Male	8	Right	19	31	63	91	68	88	90
2	Female	10	Left	21	33	73	95	70	90	92
3	Female	11	Right	18	34	66	87	65	87	105
4	Male	6	Right	20	11	65	96	60	89	91
5	Male	9	Right	22	31	66	91	64	90	90
6	Male	8	Left	24	28	71	92	70	91	89
7	Female	11	Right	17	34	68	89	72	89	91
8	Male	10	Left	20	31	68	96	75	90	88
9	Male	14	Right	19	38	71	91	70	92	89
10	Female	9	Right	21	27	68	91	80	90	91
11	Male	10	Left	18	31	73	96	75	90	89
12	Male	11	Right	25	33	71	92	70	91	90
13	Female	13	Left	20	34	73	88	76	90	88
14	Female	10	Left	18	28	68	91	78	88	87
15	Male	11	Right	19	31	63	89	70	90	90
16	Female	13	Right	22	34	73	92	72	88	95
17	Male	9	Left	21	27	63	91	68	90	91
18	Male	10	Right	18	31	73	95	69	91	90
19	Female	11	Left	19	33	71	92	70	90	90
20	Male	12	Right	20	31	68	89	74	89	88
21	Female	10	Right	22	34	65	92	64	90	89

Fig. 2



Boy, age 6 years, case No.4, diagnosed the Dias–Tachdjian pronation–eversion external rotation physeal fracture of right distal tibial epiphysis and fibula, American Orthopedic Foot and Ankle Society–Ankle and Hindfoot scoring 11 during preoperative assessment, 65 postoperation and 96 at 20 months follow-up. Lateral distal tibia angle was 60 degree in the preoperative assessment, 89 degree postoperation and 91 degree at 20 months follow-up.

postoperation and the differences between preoperation and last follow-up were statistically significant ($P < 0.05$). During the last follow-up, 19 cases had normal LDTA and no ankle varus, whereas two patients, a 13-year old girl and an 11-year old boy experienced a slight ankle varus that did not affect their daily activities. The girl's physeal plate was almost mature and the varus deformity did not worsen. The boy had the growth potential, and the ankle varus progressively aggravated leading to the second surgery, which possibly produced a satisfactory effect (Table 1). Among 21 cases, 2 had pressure ulcers in the heel 7 weeks after removing gypsum, which healed following the change of dressing and antibiotics. Typical cases are shown in Figs. 2–4.

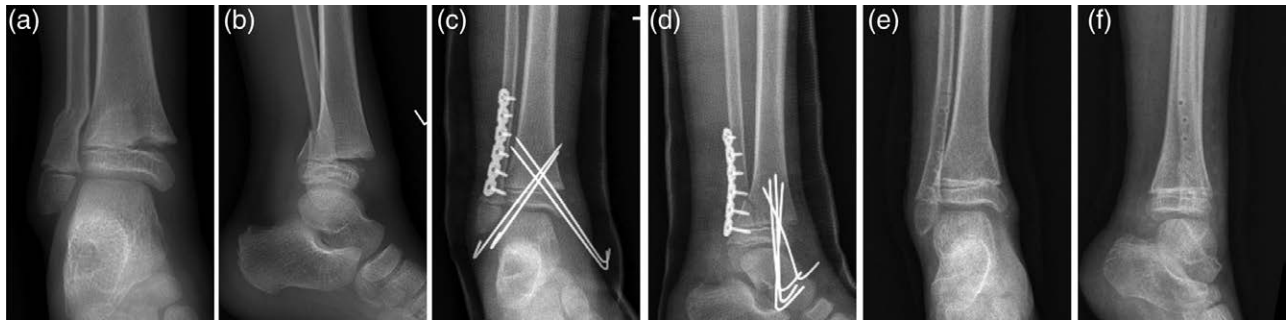
Discussion

The distal tibial physeal fracture is very common in childhood, making up for around 1/3 of all fractures in

children [1]. Salter–Harris classification is most widely used for physeal fractures; however, it is limited to an ankle fracture. In 1978, Dias and Tachdjian [7] modified Lauge–Hansen classification and grouped the child ankle fractures into four subtypes comprising the Salter–Harris classification. PEER fracture is the typical distal tibial Salter–Harris I or II fracture complicated with the fibular fracture. In the current study, all 21 patients were Salter–Harris II fracture.

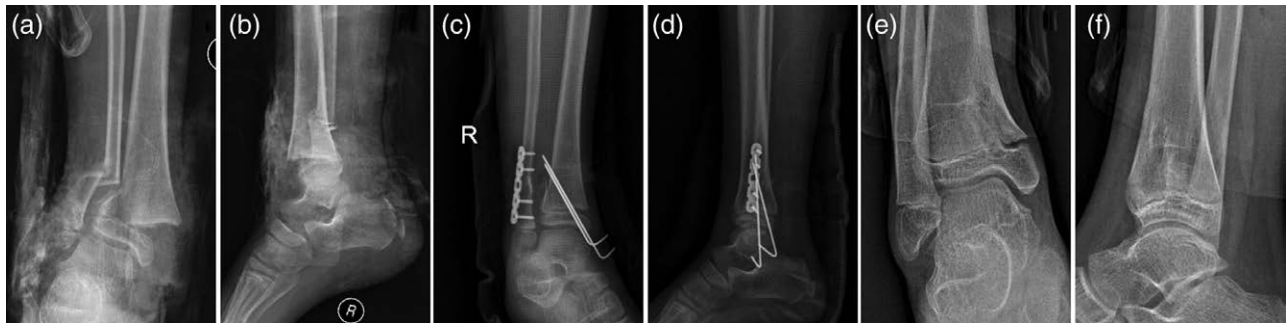
Stable distal tibial Salter–Harris II fracture without displacement usually requires the following treatment: short leg or bent long leg plaster fixation for 3–4 weeks followed by plaster cast or walking splint for 2–3 weeks. The authors advise X-ray check every week to confirm that there is no displacement in the cast. For unstable displaced Salter–Harris I or II distal tibial physeal fracture, acceptable or suitable reduction are still controversial.

Fig. 3



Girl, age 10 years, case No.14, diagnosed the Dias–Tachdjian pronation-eversion external rotation physeal fracture of left distal tibial epiphysis and fibula, American Orthopedic Foot and Ankle Society–Ankle and Hindfoot scoring 28 during preoperative assessment, 68 postoperation and 91 at 18 months follow-up. Lateral distal tibia angle was 78 degree in the preoperative assessment, 88 degree postoperation and 87 degree at 18 months follow-up.

Fig. 4



Boy, age 11 years, case No.3, diagnosed the Dias–Tachdjian pronation-eversion external rotation physeal fracture of right distal tibial epiphysis and fibula, American Orthopedic Foot and Ankle Society–Ankle and Hindfoot scoring 34 during preoperative assessment, 66 postoperation and 87 at 20 months follow-up. Lateral distal tibia angle was 65 degree in the preoperative assessment, 87 degree postoperation and 105 degree at 20 months follow-up. X-rays in the last follow-up show bone bridge and varus of the ankle joint.

Barmada *et al.* [8] made expectant treatment for distal tibial Salter–Harris I and II fractures finding the premature physeal closure in 60% of patients (14/20) with fracture gap >3 mm after reduction and 17% of patients (4/24) with fracture gap <3 mm. Yet, Park *et al.* [9] found no significantly different effects of operative and nonoperative treatment for Salter–Harris II distal tibial fractures with a residual gap of >3 mm. Nevertheless, the authors still considered that surgery might reduce the rate of premature physeal closure for PEER fracture for the high rate of premature physeal closure in this type of fracture, although Russo *et al.* [10] suggested that surgery might not be very effective for patients with residual gap >3 mm after reduction. In the present study, we enrolled PEER patients and conducted open reduction to reduce the rate of premature physeal closure, regarding residual gap >3 mm. From the medial incision in the tibia, periosteum entanglement was observed in all 21 cases. The periosteum was pulled out and the second reduction was conducted, followed by Kirschner wire insertion to fix the fracture end and

maximally reduce the rate of premature physeal closure. Our results suggest that this type of fracture should be treated by open reduction and periosteum removal to maximally reduce the rate of premature physeal closure.

Fibular PEER fracture has not yet been fully elucidated. Blackburn *et al.* [11] suggested that stable fibular fracture does not require internal fixation, whereas unstable fibula after reduction just needs closed reduction and internal fixation with the Kirschner wire. In the static model of the lower limb, Lambert [12] found that fibula bore 1/6 of body weight when the ankle joint stood. Strauss *et al.* [13] proved that fibular fixation was helpful for the maintenance of tibial reduction. However, Taylor and his team [14] reported that tibial fracture could heal even if fibula was not fixed and fibular fixation had no effect on the postoperative tibial line of force. Furthermore, Weber *et al.* [15] reported that fibular fixation could significantly reduce the movement of tibial fracture end for combined tibial and fibular fracture which was not strongly fixed but

had no significant advantages for plate or bone nail fixation. In the present study, we used Kirschner wires to fix the tibia and a locked reconstruction plate to fix the fibula; the result shows that our fixation partly reduces the residual gap in the physeal fracture of distal tibia and increases the stability of fracture. The fibula fracture line is still a long enough distance from the epiphysis line, and the follow-up result shows that the locked plate did not interfere the epiphysis function. The result demonstrates that both AOFAS-AH score and LDFA improved significantly from preoperation to postoperation even for the patient wearing a cast ($P < 0.05$), and the AOFAS-AH score improved from postoperation to last follow-up ($P < 0.05$). The average LDFA improved in the last follow-up which indicates that the reduction and fixation bring the good midterm result. In addition, patients could do load-bearing and functional exercises very early after operation. They also benefited from fracture healing and reduction of complications.

One of the early and severe complication of ankle Dias–Tachdjian PEER physeal fracture is osteofascial compartment syndrome. To timely detect and prevent this complication, all patients were asked to raise the diseased limbs in order to observe levels of pain and toe activity. If this complication was suspected, plaster open arthrolysis was conducted.

One of the long-term complications is premature physeal closure, which occurs in up to 50% of PEER fractures as reported by Michael *et al.* [16]. However, in the present study, only two patients (9.5%) had premature physeal closure in the X-rays, and there were slightly ankle varus that did not affect their daily activities during the last follow-up. The obvious inconsistencies with previous studies might be explained by small sample size and short follow-up period. Physeal arrest may appear 2 years postoperation. Besides, the medial–lateral incision in all cases, regard of residual gap >3 mm after reduction, fixes fibula and removes curled periosteum, thus reducing the incidence of premature physeal closure.

There are still disadvantages in one-stage medial–lateral combined incision open reduction internal fixation methods; for example, the patients need additional surgery for plate removal. There are also some limitations in the previous study. First, we did not set a comparison group in our research. Second, the follow-up time is not long enough, and more clinic results are needed with long-term follow-up.

In conclusion, medial–lateral combined incision can decrease the incidence of premature physeal closure regard of residual gap >3 mm after reduction and thus should be a treatment choice for PEER fracture.

Acknowledgements

This study was approved by the ethics committee of Hunan Provincial People's Hospital, the First Affiliated

Hospital of Hunan Normal University. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was waived by the committee because of the retrospective nature of the study. F.X. and B.L. contribute equally to this study, and they share co-first author. J.W. conceived, coordinated and designed the study. F.X. and B.L. performed data acquisition. S.X. wrote the paper. H.L., X.L. and K.F. did the follow-up with the patients. Z.T. and B.L. did the data analysis; S.C. and F.L. carried out the data collection and revised the paper. All authors reviewed the results and approved the final version of the manuscript. This research is funded by Natural science foundation of Hunan province China (2019JJ50324).

Conflicts of interest

There are no conflicts of interest.

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