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ORIGINAL STUDY

Angular deformity development after the distal tibial physeal fractures

Barış Özkul, Mehmet Selçuk Saygili, Engin Çetinkaya, Fatih Arslanoğlu, Ilhan A Bayhan, Bilal Demir, Ali Çağrı Tekin

Metin Sabanci Baltalimani Bone Diseases, Training and Research Hospital, Department of Orthopaedic Surgery and Traumatology, Turkey

Several clinical and radiological factors can be prognostic in the development of angular deformity following physeal injuries of the distal tibia. One of the radiological parameters, premature physeal closure (PPC), can be detected during postoperative follow-ups. Aim of our study was to identify the prognostic factors in development of angular deformity and its relationship with PPC.

One hundred and four patients treated due to physeal injuries of the distal tibia were included in our study. Patients were divided into three groups based on Salter-Harris (SH) classification. The intergroup relationships between sex, age, the amount of energy sustained during injury, premature physeal closure, the amount of residual gap, and deformity were analyzed.

Angular deformity developed in 25% (3/12) of SH Type 2, in 60% (9/15) of Type 3 and 30% (3/10) of Type 4 patients with PPC. A residual displacement of more than 2 mm, age and premature physeal closure were specified as significant risk factors for development of angular deformity.

2 mm limit for residual displacement and findings of premature physeal closure in the radiological evaluations during follow-ups are prognostic factors in avoiding malalignment of the distal tibia.

Level of evidence: Level 3.

Keywords : distal tibial fractures; premature physeal closure; salter harris classification; deformity.

INTRODUCTION

Injuries of the ankle growth plate is the second most common physeal injury of the childhood and comprises 6% of all fractures of the tibia *(8,25)*. These injuries are typically observed among children 10 to 12 years of age, usually as Salter-Harris (SH) Type 1 and Type 2 fractures followed by Type 3 and Type 4 fractures *(21,24)*.

Complication rates varying from 2 to 14.1% have been reported after injuries of the ankle growth plate with the premature physeal closure (PPC) the most encountered one *(3,9,17)*. Bridging bone (bar)

■ Barış Özkul
■ Mehmet Selçuk Saygili
■ Engin Çetinkaya
■ Fatih Arslanoğlu
■ Ilhan A Bayhan
■ Bilal Demir
Metin Sabanci Baltalimani Bone Diseases, Training and Research Hospital, Department of Orthopaedic Surgery and Traumatology, Turkey
■ Ali Çağrı Tekin
Okmeydanı Education and Research Hospital, Department of Orthopaedics and Traumatology, Istanbul, Turkey
Correspondence : Barış Özkul, Metin Sabanci Baltalimani Bone Diseases, Training and Research Hospital, Department of Orthopaedic Surgery and Traumatology, Turkey
E-mail : drbarisozkul@hotmail.com

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or partial growth arrest secondary to inappropriate treatment may cause PPC *(6,19)*.

PPC is a radiological finding detected in follow-up examinations of physeal injuries and directly related with the injury *(17,22)*. In patients with PPC, findings of malalignment and limb length discrepancy at the long term follow-up, is pointing out its clinical importance *(2,22)*. Although, the predisposional factors for PPC after physeal fractures of the distal tibia have been investigated in several studies, there is no consensus on the relationship between PPC and angular deformity. The aim of our study was to identify the predisposing factors in the development of angular deformity following physeal plate injuries of the distal tibia treated with closed or open reduction and the clinical importance of PPC prior to deformity formation.

MATERIAL AND METHODS

The medical logs of 146 patients treated with closed or open reduction due to physeal fractures of the distal tibia in two different Training and Research hospitals between 2004 and 2013 were retrospectively evaluated. Patients with incomplete follow-up data, with a follow-up period of less than 20 months, those underwent surgery after the seventh day, received treatment for their non-displaced fractures in the outpatient clinic and those with open fractures (n=42) were excluded. The 104 (79 males (69%), 25 females (31%)) patients included in the study had a mean follow-up period of 55 (range: 20 to 130) months and a mean age of 11.4 (range: 6 to 14) years. Our study population of 104 patients were divided into three groups based on the SH classification.

Patients who were treated with cast following closed reduction under emergency room conditions and those treated with internal fixation following closed or open reduction under operating room conditions were included to the study. The treatment protocol was closed reduction and plaster in 15 (14%), closed reduction with percutaneous pinning in 34 (32%), and open reduction with internal fixation in 55 (54%) patients. Overall, 47% (49/104) of the patients were treated with closed reduction while the remaining 53% (55/104) received open reduction. Postoperative radiographs revealed an inadequate reduction in three patients, which required repeat surgery. These patients were included in the study with their operative data from the last surgery. Kirschner wires (K-wire), 4 mm cannulated screws and malleolar screws were used as fixation materials. Plaster splints were removed after an average of 3 (range: 2 to 5) and K-wires after an average of 5 (range: 4 to 6) weeks. Partial weight-bearing was allowed after a period of 6 to 9 weeks of cast application in closed reduction patients. Patient data regarding age, sex, Salter-Harris classification, the amount of residual gap, PPC, the mechanism of injury, reduction type and preoperative and postoperative complications were evaluated. Angular deformity more than 10 degrees was determined as primary outcome measure.

Radiological Evaluation

Anterior/posterior and lateral ankle radiographs taken before and after reduction were assessed for radiological evaluation. All measurements were performed by a single author using the Infinitt PACS system (Infinitt Healthcare Co., Seoul, South Korea). The amount of residual displacement; that is the longest distance between the physeal line and metaphysis of the patients was noted. Direct radiography and orthoroentgenography were used in an attempt to evaluate the deformities and limb length discrepancies in patients with growth arrest. PPC was included in the study as an interim radiological parameter from the follow-up period. Sclerotic appearance, osseous bar formation, narrowing or closure of the physeal line during follow-up radiological examinations was accepted as PPC. An angulation of more than 10 degrees in the sagittal or coronal plane was deemed as deformity. Patients were divided into three groups based on the Salter-Harris classification, as Type 2, Type 3 and Type 4 for further evaluation.

Logistic regression analysis was performed to determine the prognostic factors using the SPSS 15.0 (Statistical Program for the Social Sciences; SPSS Inc., Chicago, IL, USA) software. Angular deformity was the dependent variable whereas sex, age, PPC, the amount of energy sustained during injury and the type of fracture were taken as the independent variables in the logistic regression analysis model. Fisher's exact test was used in evaluation of categorical variables.

RESULTS

The distribution of age, sex, PPC, the amount of residual gap, the amount of energy sustained during injury and deformity parameters within the groups are shown in (Table I). Mean time to detection of the PPC was found 7 (range: 3 to 10) months. Angular deformity of more than 10 degrees in the sagittal/coronal plane was detected in 7% (3/44) of the patients with SH Type 2, 29% (11/37) of the patients with SH Type 3 and 17% (4/23) of the patients with SH Type 4 fractures, totaling to 17% (18/104) of the patients. Angular deformity was present in 25% (3/12) of SH Type 2 patients, 60% (9/15) of SH Type 3 patients, and 30% (3/10) of SH Type 4 patients who also had PPC (Fig. 1). In the logistic regression analysis model depicted in (Table II), a statistically significant relationship of patient's age and residual gap amount of more than 2 mm was found with development of angular deformity ($p<0.001$). No statistically significant relationship was observed between the amount of energy sustained during injury, PPC, type of fracture and development of angular deformity (Table 2). Fisher's exact test revealed a statistically significant relationship between PPC and development of angular deformity ($p<0.001$). Level of sensitivity for PPC before deformity development was 83% whereas its specificity was at 74%. Despite the lack of a statistically significant relationship between PPC formation and SH fracture type in the post-fracture period ($p=0.304$), a significant relationship was noted with the residual gap amount of more than 2 mm ($p<0.001$) (Table II). Development of angular deformity and SH Type 2 fracture had no significant relationship whereas significant relationships were detected with SH Type 3 and 4 fractures, as shown by the Fisher's exact test ($p=0.022$).

DISCUSSION

Following physeal injuries of the distal tibia, rates of growth arrest rates varying from 2 to 14.1% have been reported in the literature *(2,17)*. The type and localization of the fracture, injury mechanism, patient's age and the quality of reduction are the impacting factors *(2,5,14,15,17,20,21)*.

Salter-Harris Type 2 fractures are the most commonly encountered type with a prevalence rate of 40% in the literature and 42% in our study *(1,17)*. This type of fractures are reported to have a low risk of growth arrest *(2,17,21,23)*. On the other hand, SH Type 3 and 4 fractures, which are far less frequent,

Table I. — Characteristics of all patients were categorized

Variables	Group 1 (SH type 2)	Group 2 (SH type 3)	Group 3 (SH type 4)	Total
Age	11.6 (6-14)	11.2 (7-14)	11.6 (9-14)	11.4 (6-14)
Sex				
Female	10 (22%)	9 (24%)	6 (26%)	25 (31%)
Male	34 (78%)	28 (76%)	17 (74%)	79 (69%)
Residual Gap				
<2 mm	38 (86%)	23 (62%)	14 (61%)	75 (72%)
≥2 mm	6 (14%)	14 (38%)	9 (39%)	29 (28%)
Energy Type				
High	7 (16%)	10 (27%)	4 (17%)	21 (20%)
Low	37 (84%)	27 (73%)	19 (85%)	83 (80%)
PPC	12/44 (27%)	15/37 (40%)	10/23 (43%)	37/104(35%)
Deformity	3/44 (7%)	11/37 (29%)	4/23 (17%)	18/104(17%)
Total	44 (42%)	37 (35%)	23 (22%)	104 (100%)

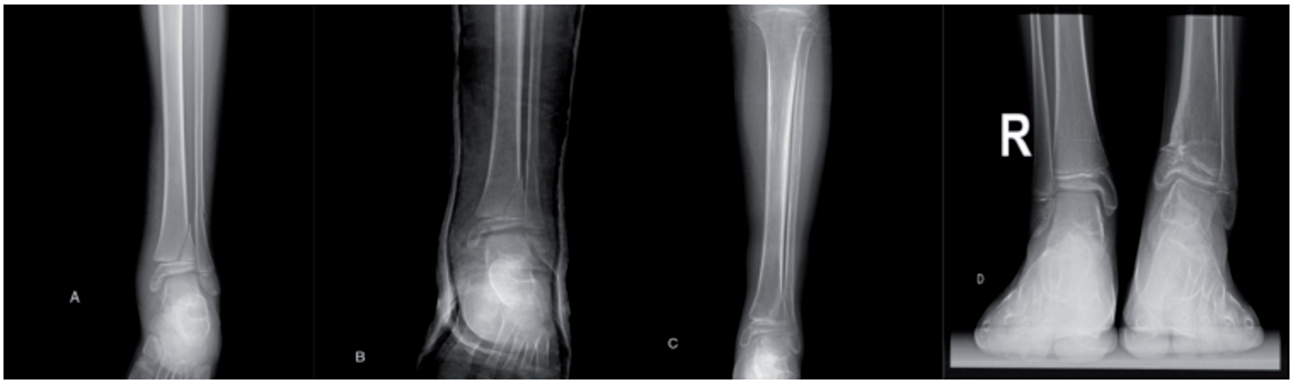

Fig. 1. — (A) 10-year-old boy with Salter-Harris type 2 distal tibia fracture; (B) After closed reduction and long leg casting but had a 3 mm residual gap; (C) After nine months follow-up radiographs demonstrating PPC at region residual physeal gap; (D) Patient radiographs taken at 3-year follow-up and angular deformity was seen

carry a higher risk for growth arrest *(2,6,16-18,23)*. The proliferative layer, held responsible for the complications, is more affected in presence of SH Type 3 and 4 fractures *(4,8)*. These fractures, which involve the medial malleolus, are called the MacFarland fractures. As they are encountered during childhood, there is a bigger risk in growth and for growth arrest development.(6) In our study, angular deformity was more prevalent in SH Type 3 and 4 fractures (29% and 17%, respectively) when compared with Type 2 (7%) fractures. Deformity development was also more significant in SH Type 3 and 4 fractures (p=0.022).

The importance of anatomical reduction in preventing the growth arrest in physeal fractures have been often pointed out to in the literature *(6,16,22,23)*. A residual displacement of 2 mm has been defined as the upper limit in reduction of these fractures *(2,10,16,21,23)*. In our study, a statistically significant relationship was found between the residual displacement of more than 2 mm, PPC and development of angular deformity (p<0.001). Although this distance has been suggested as 3 mm in some studies, we do not recommend passing beyond the threshold value of 2 mm *(20,22)*. Although, anatomical reduction is strictly recommended in the surgical treatment of the fractures of the growth plate, it is not solely sufficient in preventing the growth deficiency. Cottalorda et al. highlighted the effect of several factors on bridging bone formation on the physeal line even if an anatomical reduction was achieved *(6)*. Crush injuries in SH Type 3 and 4 fractures that involve the medial malleolus is one of these factors and the prevalence of deformity development after such fractures is between 14 and 40% in the literature and 25% in our study *(1,8,12,18)*.

The amount of energy sustained during physeal injuries may have an effect on the magnitude of the damage on the proliferative layer. High-energy injuries have been shown to have an impact on growth arrest *(17,20)*. However, no significant relationship was found between the amount of energy sustained and development of angular deformity in our logistic regression analysis (p=0.584). Another important factor in development of angular deformity following physeal fractures is the expected time for growth *(22)*. Patients with an expected time for growth less than two years carry a lower risk of deformity. Triplanar and Tillaux fractures which are seen during the late childhood possess a low risk for development of angular deformity *(7,17)*. If we are to take all patients into account in our logistic regression analysis model, we can observe a significant relationship between the patient's age and development of angular deformity (p=0.013). Even though the risk of deformity development is lower in older children, we recommend close follow-up of the patients in the post-treatment term.

Premature epiphyseal closure is directly related with Salter-Harris fractures and the literature holds numerous studies investigating the relationship between them *(2,17,21,22)*. The prevalence of PPC following physeal fractures have been reported to vary between 2 and 40% *(17,21,22)*. Jeffrey T. et al. reported the incidence of PPC in SH Type 2 fractures alone as 25% and 22% in SH Type 1 and 2 fractures combined *(17)*. The corresponding rate in our study was 27%. The three types of SH fractures had no statistically significant difference between each other when evaluated in terms of PPC development (p=0.304). The deformity incidences in PPC patients that required surgery was reported as 33% in Leary et al.'s and 64% in Barmada et al.'s study *(2,17)*. On the other hand, it was also suggested that the detection of PPC in the follow-ups did not necessarily lead to angular deformity *(2)*. Russo et al. and Spiegel et al. could not demonstrate a significant relationship of PPC with length discrepancy and angular deformity *(22,24)*. However, Russo et al. performed their study only on patients with a short expected time for growth and SH Type 2 patients. In our study, angular deformity developed in 40% (15/37) of the patients with PPC and a statistically significant relationship was detected in the follow-up period between the patients who developed PPC and development of angular deformity (p<0.001). In evaluation of the patients, which developed PPC, those who had a residual displacement of more than 2 mm developed deformity significantly more (p<0.001). In addition, we did not find a statistically significant relationship between the deformity development following PPC and SH types (p>0.001). Fisher's exact test revealed a 83% level of sensitivity and 74% specificity for PPC in deformity development. Our data prove that PPC is a radiological indicator in prediction of deformity development in the post-fracture period, however, this does not necessarily mean that deformity will develop in every patient with PPC. For instance, angular deformity developed in three of our patients who did not have PPC. We believe that the damage on the physeal lines of these patients might have developed after their final follow-ups, hindering our ability to detect the PPC.

As the amount of residual gap following closed reduction or open surgery increases, a significant increase will also be seen in the incidence of growth arrest *(2,16,17,22)*. In presence of a displacement beyond the upper limit or an intra-articular gap after closed reduction, open reduction and arthrotomy must be performed *(6,10,23)*. According to Spiegel et al., the rotation of the displaced medial fragment could best be achieved with open reduction *(24)*. However, no significant relationship was

Table II. — Logistic regression analysis of angular deformity

	Sig.	Odds Ratio	95% C.I.for Odds Ratio
Sex	.582	.545	.063
Residual Gap	.002	20.592	3.046
SH Type	.526	.717	.257
PPC	.111	.192	.025
Energy Type	.584	1.618	.290
Age	.013	1.817	1.137
Constant	.097	.012	

Fig. 2. — (A) 9-year-old boy with Salter-Harris type 3 distal tibia fracture; (B) After open reduction and early follow-up view but had a 4 mm residual gap; (C) Seven months after injury, partial PPC was present; (D) At final follow-up angular deformity was seen

found between open or closed reduction and PPC or deformity development in our study (p>0.001). We believe the quality of the reduction is a more prognostic factor in growth progress than the type of reduction (Fig. 2).

Physeal growth arrest of the distal tibia will manifest itself with impairment of the joint biomechanics, angular deformities and limb length discrepancies in the long term *(3,22,23)*. Pain and progressive arthrosis in the tibiotalar joint are the expected complications of tibial deformities *(11,13)*. Williamson and Staheli et al. recommended resection of the osseous bar and corrective osteotomy in deformities exceeding 10 degrees *(26)*. Barmada et al. reported that 64% of their patients with PPC required a second surgery in the following period due to length discrepancy and angular deformity *(2)*. In our study, 11 (61%) of our patients who developed angular deformity had to undergo a surgical intervention (epiphysiodesis, corrective osteotomy, lengthening) for the deformity. Limitations of our study included its retrospective design, performance of surgeries by more than one surgeon and the exclusion of the data regarding the implants used and number of reductions from the study.

Our study has shown that PPC is an important radiological data in the follow-up of SH Type 2, 3 and 4 fractures of the distal tibia, which we most commonly encountered. We concluded that the incidence of angular deformity was higher in patients who developed PPC in the follow-up period and particularly in those who also had a displacement of more than 2 mm. We believe our study data will be valuable for researchers in predicting and preventing the complications encountered after physeal injuries of the distal tibia.

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