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Original Article

What is the reason for out-toeing gait on the injured side after surgical treatment of distal tibia physeal fractures?

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Abstract

Aim: The aim of this study was to analyze the cause of out-toeing gait pattern in children who underwent anatomic reduction and internal fixation for distal tibial physeal injury.

Material and Methods: This IRB-approved, Level IV review study included traumatic distal tibia epiphyseal injury treated surgically at a single institution between 2010 and 2015. Patients were called back to return for additional follow-up. All clinical (foot progression angle-FPA, hip rotations, thigh foot angle-TFA) and radiological (distal tibial measurements) evaluations were done by 2 independent observers to assess inter- and intra-observer reliability using intraclass correlation coefficients (ICC).

Results: There were 38 patients with an average age of 11.4±3.8. There was a non-significant trend noted towards externally in FPA on the injured side. TFA was similar in both extremities (p: 0.56). Hip external rotation was significantly high in injured side, whereas hip internal rotation was similar. Hip external rotation was significantly high.

Conclusion: Anatomic joint reduction is mandatory to prevent growth arrest and to maintain lower extremity alignment. Considering that there is no pathology of the hip and no radiologic signs of mal-alignment of the ankle, we think that hip external rotators may shortened due to post-operative resting position, which was ended up with out-toeing gait pattern on the injured side.

Keywords: Ankle fracture; out-toeing; pediatric fractures; physeal fractures

INTRODUCTION

The most common site for physeal injury after the phalanges (fingers) and distal radius is the distal tibia accounting for 9% to 18% of all physeal injuries (1-3). The overall incidence of pediatric ankle fractures is approximately 0.1%. Because of the later closure of the lateral tibialphysis in boys, ankle fractures occur twice as often in boys as in girls (1,2,4). Although the overall incidence seems uncommon, those with intra-articular involvement of the distal tibial epiphysis in children are the most problematic complications (3-5).

The most common ankle physeal injury was reported for Salter–Harris type II fractures with an incidence of between 39.6% and 67%, followed by type III fractures (between 13% and 21.7%) and type IV fractures (between 13% and 20%) (6-9). There is a risk of premature growth plate arrest with angular deformity, leg length discrepancy (LLD) and early articular degeneration (1,10,11). Premature growth arrest is unpredictable and can occur without any severe displacement (10,12). Although open reduction internal fixation has traditionally been thought to be a risk factor for growth arrest, open-anatomical reduction is usually mandatory and may prevent physeal complications (6,10,13,14). Ankle fractures may result in rotational problems in pediatric population.

Rotational problems of the lower extremities are relatively common in infants and children after fractures (15). In addition to cosmetic concerns, some recent studies have shown that torsional malalignment may be a risk factor for early degeneration in the joints of the lower extremities, especially on the patella-femoral joint (16,17).

Externally rotated foot progression angle (FPA) during gait is one of the signs of rotational lower extremity problems which we have noticed in the children who underwent anatomic reduction and internal fixation for distal tibialphyseal injury (Figure 1). Our aim was, whether this was due to premature growth arrest or not. Petratos et al. reported that angular deformity was observed after epiphysial fractures of the ankle (18).Nathan et al. proposed the development of ankle valgus in pediatric

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patient groups receiving following vascularized fibular graft harvest (19).

In this study, we retrospectively analyzed the cause of out-toeing gait pattern in children who were operated on for distal tibialphyseal fractures.

Figure 1. Radiographic images of the fracture (preoperative ,postoperative and measurement at the last follow-up)

MATERIAL and METHODS

This is an IRB-approved retrospective review of children between 5 and 15 years old, diagnosed with traumatic distal tibia epiphyseal injury and treated surgically at a single institution between 2010 and 2015. Patients with an open distal tibialphysis and selected for open reduction internal fixation were included in this study. Patients with a diagnosis of congenital lower extremity deformities, neurologic disease, skeletal dysplasia, metabolic bone disease, or treatment with conservative methods were excluded. Charts were analyzed for demographic features, the mechanism of injury, type of epiphyseal injury according to Salter-Harris classification, type of surgical technique and fixation material used, and time interval between injury and surgical procedure.Our study complies on World Medical Association Declaration of Helsinki"Ethical Principles for Medical Research Involving Human Subjects", (amended in October 2013).

Assessment of Functional Outcomes and Lower Extremity Rotational Profile

Patients were called back to return for additional follow-up assessment of functional outcome by foot progression angle (FPA), hip rotations using Craig's test in prone position, thigh foot angle (TFA), ankle range of motion, leg length discrepancy (LLD) and the American Orthopedics Foot and Ankle Score (AOFAS) (15). Patients' non-injured sides were used as a control group. A goniometer was used during the measurements. LLD was measured using a tape measure.All clinical evaluations were done by another independent physician. Inter-observer reliability for each measurement was assessed using intraclass correlation coefficients (ICC).

Foot Progression Angle (FPA)

The foot-progression angle was determined according to the progression line by plotting the foot longitudinal axis after the children were pressed on the ink with the bare foot and the white line was drawn on a straight line on the platform.

Hip Rotations

Patients underwent a Craig's test at the outpatient clinic to check for hip rotations (external and internal). When the patient was lying in the prone position, the knee was placed in the 90° flexion position on the side to be tested. The inspector palpated the greater trochanter with one hand, and brought the other hand to the internal rotation. During this process, no extra force was applied to the limb; gravity was used. The angle between the tibia and the vertical plane was measured by goniometer, and the angle of femoral anteversion was determined and photographed. (19)

Thigh-Foot Angle (TFA)

The thigh foot angle was measured in the prone position. The patient was admitted to the examination table in a prone position. Both knee joints were brought to a 90 ° flexion to measure the angle between the foot axis and the thigh axis, connecting the heel and the second metatarsal. During measurement, the foot was released in its natural position.

Radiographic Measurements and Intra- and Inter-observer Reliability

Radiographic parameters, including anatomic distal tibial angle in sagittal and coronal plane and any sign of joint narrowing, were assessed by obtaining standing antero-posterior and lateral x-rays of both ankles at last follow up. Each author calculated the angle between the line connecting the midpoints of the tibia medullas on the anterior posterior and sagittal planes and the line drawn parallel to the tibia plafond. Radiographic measurements were made by 3 independent observers to assess the distal tibial geometry. Inter- and intra-observer reliability for each of the radiographic measurements was assessed using intraclass correlation coefficients (ICC) calculated from 2 sets of repeat measurements on a subset of 30 radiographs, with each set of measurements at least 1 week apart for each observer. Agreement was considered excellent for ICC >0.80, very good for 0.70-0.80, good for 0.60-0.70, fair for 0.40-0.60, and poor for <0.40.

RESULTS

There were 38 patients (16 girls and 22 boys). The mean age at initial presentation with the injury was 11.4±3.8 years old. The mean follow up was 3.2±1.4 years (range 1.2-7.3 years). The most common mechanism of injury was fall from a height with 26 patients (68 %), followed by motor vehicle accident with 6 patients (16 %) and sports injury with 6 patients (16 %).

The majority of the cases were Salter-Harris type 2 injuries (34 %), followed by Salter-Harris type 3 (37 %) and Salter-Harris type 4 (29%) (Table1).

Table 1. Demografics of the patients		
Sex (n=38)	**16 girls**	**22 boys**
Mean age at injury	11.4 +/- 3.8 years	
Mean follow-up	3.2 +/- 1.4 years (1.2-7.3 years)	
Salter- Harris Type	Type II	34%
	Type III	37%
	Type IV	29%
Fixation Material	Cannulated screw	27(71%)
	Kirschner wire	11(29%)
Injury Mechanism	Fall of a height	68%(n=29)
	Motor vehicle accident	16%(n=6)
	Sport injury	16%(n=6)

All cases had unilateral involvement and underwent open anatomic reduction and fixation using either cannulated screws (27 patients, 71 %), or Kirschner wires (11 patients, 29%). The average time interval between injury and surgical procedure was 74.2 hours (+/- STD 53.8 hours). Postoperative long leg casts were used in the all cases.

Table 2. Clinical assesment of the patients at last follow-up	
Foot progression angle	
Injured side	16.5 °
Non-injured side	10.4 °
Hip external rotation	
Injured side	42 °
Non-injured side	30.4 °
Hip internal rotation	
Injured side	53.8 °
Non-injured side	52.4 °
Tigh foot angle	
Injured side	-8.5 °
Non-injured side	-7.9 °

Intra- and inter-observer reliability of FPA and hip rotations were very good (ICC:0.792) and TFA was excellent (ICC:0.857). According to the clinical assessments, there was a non-significant trend noted towards the external in FPA on the injured side (16.5° vs. 10.4°). TFA was nearly similar in both extremities (-8,5 vs. -7,9°). Hip external rotation was increased on the injured side (42° vs. 30.4°), whereas hip internal rotation was nearly similar in both extremities (53.8 vs. 52.4°).LLD was noted in only 1 patient who had premature growth plate arrest. The average AOFAS score was 98.5 ± 3.8. Few patients had pain (3 patients - 8 %) or a limp (2 patients -5%) at the last follow up (Table 2).

Intra- and inter-observer reliability of distal tibia measurements was excellent for the coronal plane (ICC:0.933) and very good for the sagittal plane (ICC:0.774). The average anatomic distal tibial angle in the sagittal plane was 81.2 degrees and in the anatomic distal tibialangle coronal plane was 87.6 at the last follow-up (Figure 2). Signs of joint narrowing were observed in 3 patients (8 %).

Figure 2. Post-operative resting position in bed

DISCUSSION

Torsional deformities may be additive or compensating, and may cause in-toeing or out-toeing gait patterns (20). The level of the problem may be in the femur, tibia and foot (20). Torsional profile in the lower extremity can be determined by evaluating FPA, internal and external rotation of the hip, and the thigh-foot angle (21). Lateral torsion of the tibia (out-toeing) is uncommon and generally does not improve as age progresses (22). In our study, we retrospectively analyzed the cause of out-toeing gait patterns in children who underwent anatomic reduction and internal fixation for distal tibialphyseal injury.

Nathan et al. Studied 31 pediatric oncology patients who underwent vascularized fibular graft surgery.They observed that ankle valgus developed in 5 patients. They reported lateral tibial atrophy and concave anterior bowing of fibula as the causes of ankle valgus. Operation age under 14 years old and short residual fibular length were shown to be significant risks (19).

Petratos et al. reported that type 3 and 4 ankle epiphysiolysis increased risk of premature growth arrest in patients without open reduction and internal fixation in the first 24 hours. In our study, LLD was observed in only 1 patient after premature growth arrest although the operations were performed at an average of 74.2 hours. The causes of premature growth arrest are multifactorial. In our opinion, early operation time is less important than reduction success (18).

The external rotation degree of the hip is one of the factors that plays a role in out-toeing formation. The degree of external rotation of the hip is slightly higher in boys and there was no significant change in later ages, even though it decreased between the ages of 6 and 8 (23). There are studies showing that the hip joint provides significant compensation for the torsional profile (24). The ability of the hip joint to move in multiple planes may be the reason for the more active role of other joints to compensate.

Staheli et al. reported that the normal values of the TFA is 10° (-5° to +30°), evaluating thigh, tibia and hind-foot rotation together [25]. Stuberg et al. found that the measurements of TFA, evaluated by three different observers, were 15.1 °, 14.3 ° and 17.6°, respectively, in normal adults with no statistical difference (26). In our study, the average TFA was 8.5° (SD ±3.6°) and similar in both injured and non-injured sides. These data showed that there is no impact of TFA on out-toeing gait pattern of the injured side in those who underwent surgical fixation for distal tibialphyseal injury.

Our observational study showed that there was a non-significant trend towards the external in FPA on the injured side (16.5° vs. 10.4°), similar TFA in both extremities (-8,5 vs. -7,9°) and increased trend hip external rotation on the injured side (42° vs. 30.4°).According to our findings, the hip joint develops a compensation mechanism towards to the external. Considering that there is no pathology of the hip joint and anatomical reduction was achieved according to radiologic findings, we hypothesise that hip external rotators may be shortened due to the post-operative resting position in bed (Figure 3).

This study has some limitations, most of which are inherent in its retrospective design.One of the main limitations is that muscle volume and length are not measured by usingmri.Assessment of clinical outcomes was limited to patients who could be re-evaluated, and follow-up was relatively short for a pediatric report. Furthermore, functional outcome was limited by the small number of patients who returned for this portion of the study. Besides the findings of this report, similar results might be expected in other lower extremity surgeries in children.

This study has several strengths. Although pediatric ankle fractures are rare injuries, the number of patients is relatively high. All clinical and radiological measurements were validated by intra- and inter-observer reliability evaluation. In the literature, prospective studies are needed to make measurements using MRI. In addition, studies to be performed in patients who have to do bed rest for a long time, whether traumatic or not, will contribute to the literature.

CONCLUSION

In conclusion, anatomic joint reduction is mandatory to prevent growth arrest and to maintain lower extremity alignment in all planes. An out-toeing gait pattern can be expected due to external rotation contracture of the hip after surgical treatment of distal tibial epiphyseal injury due to hip external rotator muscles may be shortened due to the post-operative resting position in bed.

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