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Growth Plate Injuries of the Lower Extremity: Case Examples and Lessons Learned

Abstract

Background: The presence of growth plates at the ends of long bones makes fracture management in children unique in terms of the potential risk of developing angular deformities and growth arrest. **Materials and Methods:** We discuss three distinct cases depicting various aspects of physeal injury of the lower extremity in children. **Results:** The case illustrations chosen represent distinct body regions and different physeal injuries: Salter–Harris II fracture of the distal femur, Salter–Harris VI perichondrial injury of the medial aspect of the knee region, and Salter–Harris III fracture of the distal tibia. The clinical presentation, pertinent history and physical findings, imaging studies, management, and subsequent course are presented. **Conclusions:** Growth plate injuries of the lower extremity require a high index of suspicion and close monitoring during skeletal growth. Early recognition and proper management of these injuries can minimize long term morbidity. The treatment plan should be individualized after a comprehensive analysis of the injury pattern in each patient. Establishing a long term treatment plan and discussing the prognosis of these injuries with the child’s caretakers is imperative.

Keywords: Children, growth plate, pediatric, physeal injuries

MeSH terms: Pediatrics, growth plate, epiphyseal cartilage

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Introduction

Nearly one-third of long-bone fractures in children involve the growth plate or physis.¹ Physeal injuries may be classified by the Salter–Harris system, initially described in 1963.² These fractures require special attention. Not only are they relatively common, but also inappropriate initial management may result in complex, progressive angular deformity, secondary to growth arrest. Thus, early recognition and proper treatment is the key. In this article, we explore three cases of lower-extremity growth plate injuries. The series includes patients presenting with physeal trauma, as well as sequelae—including growth arrest and progressive angular deformity—secondary to physeal trauma. While there is no one “perfect answer” to each case, the series is a depiction of possible management approaches for these injuries. This manuscript shares the various aspects of diagnosis, imaging, and management of early and late sequelae of these physeal injuries.

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Cases and Analyses

Case 1

Initial presentation

11 year old boy presented 9 days after a fall from his bicycle (sustained out of the country), in a long leg cast on his left side. Radiographs [Figure 1A a,b] demonstrated an anteromedially displaced Salter–Harris II fracture of the left distal femur, with minimal comminution. His metaphyseal (Thurston–Holland) fragment was medial, and the metaphyseal spike of the proximal fragment was displaced posterolaterally. The neurovascular examination of the distal extremity performed after removal of the cast was unremarkable. The patient was placed in proximal tibial traction and planned for open reduction and internal fixation.

Clinical course

Following open reduction and internal fixation using smooth wires, which were cut under the skin [Figure 1A c,d], and placement in long-leg cast, the patient was mobilized non weight bearing with crutches. Two months later, he was walking independently with a mild limp and no fracture-site tenderness. Radiographs confirmed a healing

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Figure 1A: (a and b) Anteroposterior and lateral radiographs of knee joint showing displaced Salter–Harris II fracture of the left distal femur (c and d) Anteroposterior and lateral radiographs of knee joint healing Salter–Harris II fracture of the left distal femur, 2 months postoperatively. The smooth k-wires were buried under the skin (e) Scanogram at 6 months after removal of hardware, valgus deformity of the left lower extremity secondary to the distal femoral malorientation

fracture with intact hardware. The pins were removed under anesthesia and the patient was placed in a knee immobilizer.

Six months later, he was found to have a 15° valgus deformity with a 10° flexion deformity of the left knee. Radiographs [Figure 1A e] demonstrated lateral mechanical axis deviation (MAD) of 3.6 cm. The patient underwent magnetic resonance imaging (MRI) [Figure 1B a], which demonstrated no clear evidence of a physeal bar, although mild irregularity of the lateral portion of the distal femoral physis was noted.

A medial distal femoral hemiepiphyseodesis with a nonlocking extraperiosteal plate was planned with the

intention to correct the valgus deformity with subsequent growth [Figure 1B b]. The patient was lost to followup and presented 30 months later. His physical examination at this time demonstrated shortening of the left limb by 2 cm, with 10° flexion contracture and a lateralized patella. Radiographically, his left MAD was 2.7 cm, laterally [Figure 1B c]. Computed tomography scan confirmed lateral patellar dislocation with early degenerative changes in the patellar undersurface and the articulating portion of the lateral femoral condyle.

While his angular deformity did show somewhat improvement, considerable genu valgum and procurvatum, and persistent lateral patellar dislocation and limb



Figure 1B: (a) Magnetic resonance T2W imaging, left knee showing the mild irregularity of the lateral distal femoral physis (arrow) without a discrete physal bar. (b) Anteroposterior radiograph, left knee, following application of a nonlocking medial distal femoral extraperiosteal plate for guided growth treatment. (c) Scanogram at 30 months after medial distal femoral hemiepiphyodesis. Compare with Figure 1A e. (d) Anteroposterior radiograph, left femur, demonstrating external fixation construct applied following distal femoral osteotomy and gradual lengthening and angular correction. (e) Full-length anteroposterior standing radiograph, after 3 months of gradual correction in external fixator. The valgus deformity and shortening of the left lower extremity has been corrected. (f) Axial cut of the magnetic resonance T2W imaging, left knee following limb realignment showing persistent lateral patellar subluxation with early degenerative arthritis

shortening, prompted a distal femoral osteotomy with lateral release of the patellar retinaculum and gradual correction with external fixation [Figure 1B d]. Over the course of external fixation, the patient performed biweekly physical therapy, with attention to patellar mobilization. After 3 months, he demonstrated clinically equal leg lengths. MAD of the left limb at this time was 0.9 cm, medially [Figure 1B e].

Following removal of his external fixator, the patient's patella continued to maltrack and laterally sublux. Clinically, his symptoms comprised pain over the anterolateral knee, in addition to crepitus with flexion and extension. Examination demonstrated lateral patellar dislocation with progressive flexion and a palpable trochlear groove with a flexed knee. Despite correction of his angular deformity and leg-length discrepancy, his patella, most recently examined

8 years after his initial injury, demonstrated chronic lateral dislocation, with symptomatic degenerative patellofemoral arthritis [Figure 1B f]. We discussed operative treatment options, including patellectomy, or patellofemoral arthroplasty, with extensor mechanism realignment.

Case analysis and learning points

According to a recent metaanalysis, 58% of distal femoral Salter–Harris II fractures result in growth disturbance, compared to the rates of 36%, 49%, and 64% among Salter–Harris I, III, and VI, respectively.³ A retrospective review of 73 distal femoral epiphyseal fractures found that the Salter–Harris classification, as well as the fracture displacement, were both significantly associated with growth arrest and complication following distal femoral physal fractures.⁴ While it has been postulated that the location of the metaphyseal Thurston–Holland



Figure 2: (a) Clinical photograph, left lower extremity deformity at first clinical presentation, showing the severe varus, limb shortening and poor skin around the medial aspect of the knee. (b) Anteroposterior radiograph of the injured left knee and distal femur. No acute fractures were identified. In hindsight, this was a type VI physeal injury involving the perichondrium of the medial distal femoral growth plate that was not appreciated. (c) This patient underwent multiple attempts at realignment such as the distal femoral valgus osteotomy seen here to correct the recurrent varus deformity of the distal femur. (d) This figure demonstrates a subsequent proximal tibial valgus osteotomy to address the recurrent varus deformity of the knee. (e) After multiple osteotomies with inability to maintain correction, this patient underwent an arthrodesis of the knee approximately 3 years after the original injury. It is unclear whether he ever underwent a distal femoral epiphysiodesis, a procedure that if done earlier would have likely avoided multiple osteotomies. The residual shortening of the left leg could have been addressed with ipsilateral limb lengthening or contralateral epiphysiodesis, and his knee joint mobility would have been preserved. (f) Full-length anteroposterior standing radiograph, left lower extremity deformity at first clinical presentation. (g) Full-length anteroposterior standing radiograph, after two osteotomies away from the apex of the deformity (due to poor soft tissues) and gradual lengthening and translation via external fixation. (h) Full-length anteroposterior standing radiograph, after gradual correction and early consolidation of the lengthening regenerate. (i) Clinical photograph at followup visit after removal of fixator showing restoration of length and alignment of the left lower extremity. (j) Radiograph, full-length anteroposterior standing, from most recent followup, showing restoration of limb length and alignment. (Parts of Figure 2 have been previously published by Sabharwal S. Fractures with Soft Tissue Injuries. Skeletal Trauma in Children. 5th Edition. Editors, Swintowski and Mencia. Volume Three. Elsevier. 2014. Permission enclosed)

fragment may influence subsequent angular deformity by protecting the physeal integrity on the side of the fragment (e.g., a medial fragment resulting in a valgus deformity, due to relatively protected growth medially), a retrospective study of twenty Salter II fractures of the distal femur found

no correlation between fragment location and subsequent varus or valgus angulation.⁵

Although MRI has demonstrated effectiveness in detecting early bone bridge formation and improving delineation

of physal fractures, it did not capture the presence of a discrete bony bar or elucidate the health of the physis in our patient's case.^{4,6} Thus, close followup of the injured distal femoral physis till skeletal maturity is necessary despite the lack of a discrete "physal bar" on advanced imaging.

This patient was likely to develop lateral instability of the patella due to posttraumatic progressive genu valgum related to asymmetric premature physal closure of the lateral distal femoral growth plate. Over time, the lateral maltracking of the patella became fixed, with secondary pseudo-articulation of the patellofemoral joint and secondary patellofemoral arthritis. In cases of patellar instability in the setting of genu valgum, correction of the angular deformity via selective hemiepiphysiodesis has demonstrated effective improvement or resolution of symptoms, without the need for surgical patellar centralization.⁷ However, this technique demands sufficient growth remaining from the lateral physis. Achieving mechanical alignment via lateral opening wedge distal femoral osteotomy has also demonstrated significant improvement in functional and radiographic

measures in patients with genu valgum-associated patellar instability.⁸ By addressing the patient's patellar instability earlier in the clinical course with deformity correction via an osteotomy instead of guided growth treatment, we may have avoided his subsequent patellofemoral arthritis and secondary bony changes due to persistent patellar subluxation, an undesirable outcome compounded by the limited reconstructive options for a young adult.

This case illustrates the importance of long term followup in physal injuries. The sequelae can develop late, sometimes several years after the index trauma. A vigilant clinician can pick up the deformity early by careful analysis of serial radiographs and intervene in a timely manner to achieve satisfactory results. The presence of an active physal plate permits limb alignment via hemiepiphysiodesis.

Case 2

Initial presentation

14 year old boy presented with deformity and shortening of his left lower extremity [Figure 2a]. He had an initial

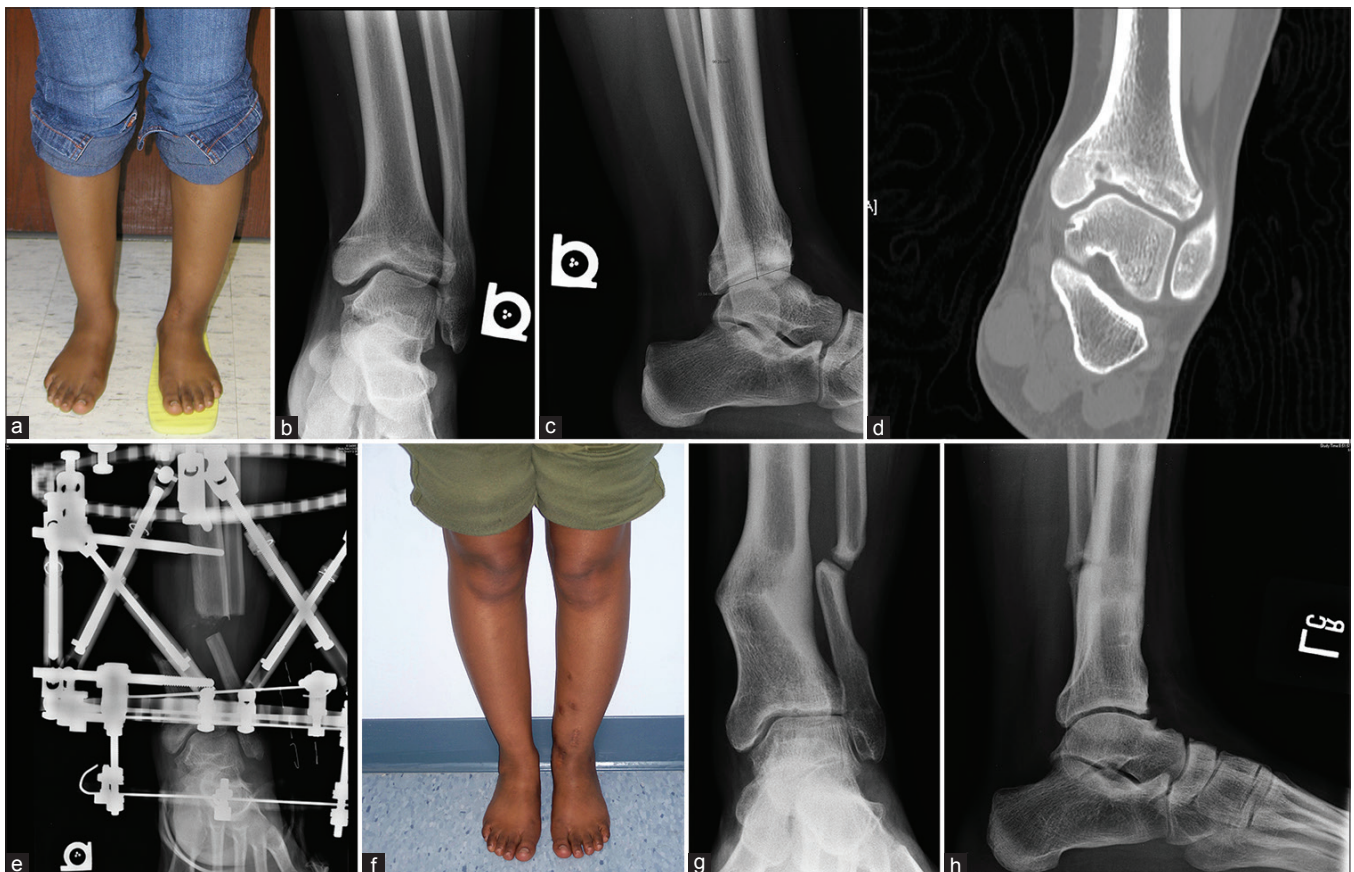


Figure 3: (a) Clinical photograph left lower extremity deformity at initial presentation showing the left distal tibial varus deformity and limb shortening. (b and c) Anteroposterior and lateral radiograph, left ankle at initial presentation showing the distal tibial varus deformity (d) Computed tomography scan, left ankle at initial presentation. Note the subchondral sclerosis and cysts at the medial portion of the distal tibial articulation. (e) Anteroposterior radiograph, after osteotomy and application of external fixator with gradual angular correction and lengthening. Note the intentional medial translation of the distal fragment due to the osteotomy being away from the apex of the deformity, at the medial distal tibial physal scar. (f) Clinical photograph followup visit after removal of fixator showing satisfactory restoration of length and alignment of the distal tibial deformity. (g) Anteroposterior radiograph, left ankle after fixator removal showing a healed distal tibial osteotomy with correction of the varus deformity and shortening. (h) Lateral radiograph, left ankle after fixator removal showing correction of the recurvatum

motorbike accident 8 years ago. At that time he had experienced a traumatic open-knee arthrotomy with soft-tissue injury and putative physeal injury of the medial aspect of the knee and lower thigh. No fractures were noted on the initial radiographs [Figure 2b]. The patient had a history of multiple previous surgeries including multiple femoral and tibial osteotomies [Figure 2c and d] to address recurrent varus deformities, multiple skin grafts, and a knee arthrodesis [Figure 2e] at other institution. Physical examination demonstrated contracted skin grafts over his thigh and around the knee, which was fused in extension. Radiography [Figure 2f] confirmed 18-cm leg-length discrepancy (13 cm femoral + 5 cm tibial) in addition to a tibiofemoral varus deformity of 28°. His presentation was consistent with a missed medial Salter–Harris VI perichondrial injury,⁹ given the initial accident’s scalping mechanism, and consequent growth arrest medially, resulting in recurrent varus deformity despite realignment osteotomies.

Clinical course

After extensive counseling with the patient and his family, he was planned for a two-level osteotomy and gradual lengthening and deformity correction of the femur and tibia in external fixation. Due to poor tissue quality at the apex of deformity with thin skin grafts, the metadiaphyses of the femur and tibia were selected as sites of lengthening and deformity correction.

Intraoperatively, multiple drill-hole osteotomies were created at the metadiaphyseal junctions of the distal femur and proximal tibia and the external fixator was applied [Figure 2g].

The patient was followed up regularly during the realignment phase and his correction schedule was adjusted accordingly. Ten months after application of the fixator, after demonstrating satisfactory healing and alignment [Figure 2h], the device was removed [Figure 2i]. On recent followup radiographs, the femoral and tibial lengthening sites had consolidated, and the lower-limb alignment and leg-length discrepancy had been surgically corrected [Figure 2j].

Case analysis and learning points

Displacement of the perichondrial ring in Salter–Harris VI injuries permits bony bridging between the epiphysis and metaphysis, which may then cause progressive angular deformity.⁹ While classically associated with lawn-mower accidents, from Rang’s work, a more recent case series demonstrated that these injuries are most commonly attributable to closed, minimally displaced injuries sustained via indirect forces, which may be treated nonoperatively with satisfactory results.¹⁰ However, cases of open Salter–Harris VI injuries, caused by a direct “scalping” mechanism, all associated with traffic accidents in the afore mentioned case series, require operative treatment.¹⁰

Operative treatment, in these cases, comprised of repeated debridement and skin grafting, as well as an anticipatory Langenskiöld procedure, utilizing free-fat interpositional graft.¹⁰ This procedure, when applied in acute management of such physeal injuries, may prevent growth arrest.¹¹ These injuries are difficult to diagnose initially due to lack of visible fracture lines on radiographs, as was the case in our patient. Had the nature of the underlying perichondrial injury been diagnosed earlier, multiple prior surgeries and a stiff, deformed knee may have been prevented. Thus, the treating surgeon should have a high index of suspicion of a perichondrial injury based on the mechanism of injury (such as a scraping “road rash” injury) in a young child. Furthermore, these young patients should be followed up with serial radiographs during their growing years to ensure symmetric growth of the adjacent growth plates.

While osteotomy at the apex of deformity would allow for angulation alone to realign the bone ends, geometry of the deformity does not dictate osteotomy level on its own. Proximity to the joint or physis, quality of bone, and (of particular relevance to our case) soft-tissue coverage must be considered in surgical planning.¹² As Paley affirms, by selecting an osteotomy level or levels away from the deformity’s apex, angulation in conjunction with translation are required to realign the bone ends (and, it follows, the mechanical axis).¹²

While the original classification includes five types of Salter–Harris fractures,⁹ this case demonstrates the presence of a distinct perichondrial Salter–Harris VI injury prone to subsequent growth arrest. These injuries can be missed often, due to low clinical suspicion and the absence of a fracture line on plain radiographs.

Case 3

Initial presentation

14 year old girl presented with abnormal gait and discomfort around the medial ankle. Her history revealed a previous left distal tibial Salter III fracture, sustained 9 years prior. This fracture was initially treated nonoperatively, and the patient was lost to followup. Physical examination and subsequent radiography [Figure 3a] demonstrated shortening of her left limb by 2.4 cm, as well as angular deformity, namely 30° of varus [Figure 3b] and 10° of recurvatum [Figure 3c]. Her left ankle dorsiflexed to 5° and plantarflexed to 15° beyond neutral. Her presentation was consistent with growth arrest secondary to a Salter–Harris III fracture of the distal tibia, extending through the medial malleolus. Advanced imaging also revealed subchondral sclerosis and small cysts in the medial distal tibia [Figure 3d], likely related to the abnormal mechanical loading secondary to the varus malorientation of the tibiotalar joint.

Clinical course

After preoperative analysis demonstrating a biplanar deformity (varus and recurvatum) and limb shortening, a distal

tibial osteotomy with external fixation was planned to guide gradual lengthening and angular correction. Intraoperatively, multiple drill-hole osteotomy 4 cm proximal to the left ankle joint and excised 1 cm of distal fibula was performed. Half-pins and wires were placed proximally and distally to the osteotomy, fixed to their respective rings, as well as through the calcaneus, fixed to a calcaneal half-ring. Gradual correction with lengthening and appropriate translation was achieved over the next few weeks [Figure 3e]. The external fixator was subsequently removed and, at a 5-year followup, her symptoms, gait abnormality, and appearance of the lower limb had improved substantially [Figure 3f]. At this time, her left ankle dorsiflexed to 5° and plantarflexed to 15° past neutral. Radiographs revealed improved orientation of the distal tibia with a healed osteotomy with intentional medial translation of the distal fragment [Figure 3g and h].

Case analysis and learning points

Distal tibial fractures constitute the most common physeal injury of the lower extremity.¹³ Anatomically, the strong ligamentous attachments distal to the horizontally oriented physis predispose the skeletally immature ankle to injuries warranting operative intervention.¹³

Open reduction is indicated in Salter–Harris III and IV fractures of the distal tibia with displacement >2 mm.¹³ If such a fracture is undisplaced and treated nonoperatively with cast immobilization, close followup not only to fracture union, but also during the next several months to years is necessary, in order to ensure symmetric growth of the injured physis.

Our patient presented several years following the injury, and her symptoms and radiographic findings were consistent with abnormal loading of the tibiotalar joint. Left untreated, this patient would have gone onto develop advanced degenerative arthritis of her ankle joint as a young adult. Thus, early recognition and appropriate realignment is prudent in such cases. If this child was still growing, a concomitant completion of the distal tibial and fibular epiphysiodesis would be indicated so as to prevent recurrent deformity with growth.

Since the osteotomy was performed away from the apex of the deformity, which was at the level of the medial distal tibial physis, appropriate translation was performed at the osteotomy site along with angular correction and lengthening.^{12,14,15}

An important aspect of physeal injuries is their close association with articular surface. Restoration of joint congruency is important to prevent degenerative arthritis. Deformity correction in children requires careful planning to achieve satisfactory results.¹² This carries more importance in weightbearing joints of the lower extremity.¹³

Discussion

The presence of growth plates at the ends of long bones predisposes children to developing unique sequelae

following physeal trauma. The child may present with distinct injury patterns; management of these fractures requires comprehensive understanding of the underlying injury and its influence on subsequent growth of the affected extremity. In addition to immediate injury-related complications, these physeal fractures are prone to long term sequelae, secondary to growth arrest. The above case series illustrates the key aspects of physeal injury, for treating clinicians to bear in mind, intending to raise the index of suspicion for physeal growth plate injuries. As these cases demonstrate, early recognition and proper management can minimize morbidity. It is imperative to correlate history and mechanism with the radiographic findings and establish an individualized treatment plan after comprehensive analysis of all available clinical information. Anticipating problems related to future growth, appropriately counseling the family and caregivers, and close followup through skeletal maturity are recommended.

Conclusions

Growth plate injuries of the lower extremity require a high index of suspicion and close monitoring during skeletal growth. Early recognition and proper management of these injuries can minimize long term morbidity. The treatment plan should be individualized after a comprehensive analysis of the injury pattern in each patient. Establishing a long term treatment plan and discussing the prognosis of these injuries with the child's caretakers is imperative.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients' guardians have given their consent for the patients' images and other clinical information to be reported in the journal. The patients' guardians understand that the patients' names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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