CHAPTER **50**

PHYSEAL FRACTURES

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INTRODUCTION

Physeal fractures can potentially lead to detrimental consequences such as limb length deformity by virtue of premature growth plate closure. It is paramount to realize the differences between pediatric and adult fractures to insure appropriate diagnosis and treatment. Attention should be focused on the unique anatomy and physiology of growth plates. The dynamic healing capability of growth plates will add new dimensions in predicting outcomes of physeal fractures. Children have unique potential to self-correct angular deformities which are not feasible in adults. With this in mind, certain angular deformities deemed unacceptable in adults would be considered acceptable in children. The age of the child and degree of injury are both important factors in predicting outcomes of physeal fractures

ANATOMY AND PHYSIOLOGY

A knowledge of the anatomic component and physiological function of growing bones is crucial in order to fully understand physeal injuries. The growth plate is composed of multiple layers, or zones of specialized cartilage cells. These cells participate in both the longitudinal and appositional growth of bone. The germinal cells, which are also referred to as resting cells, are located adjacent to the epiphysis. These cells are well-embedded in strong matrix. The next layer of cells is composed of columns of cells undergoing rapid mitosis and hypertrophy, referred to as the zone of proliferation. This zone is also embedded in an abundance of intercellular matrix. It is considered the strongest layer of the physis. The hypertrophic cells gradually disintegrate to form the zone of enchondral ossification where chondrocytes prepare to ossify. The local oxygen tension level is increased here due to the invasion of metaphyseal blood vessels promoting ossification of the matrix ground substance. The amount of cementing matrix substance decreases with progression towards the metaphysis. The relative lack of intercellular matrix in the zone between the hypertrophying cells and ossifying cells makes it the weakest area of the physis. With an understanding of the relative strengths of different layers of the physis, it is not surprising that cleavage is most likely to occur in the physeal-metaphyseal junction.[1] Keep in mind that as long as the proliferating and hypertrophying cells remain attached to the epiphysis with its epiphyseal blood supply undisturbed, there is no reason why growth disturbance should occur.[2]

There are three primary sources of blood supply to growing bones. The nutrient artery is the major source of blood supply to the diaphysis. The metaphyseal sinusoids supply the metaphyseal side of the growth plate. The epiphyseal vessels enter through the joint capsule and supply the majority of the germinal and proliferating cells. The periosteal and perichondral vessels supply the peripheral portion of the physis. When fracture of an extra-articular physis occurs, both the epiphyseal and metaphyseal blood supplies are usually maintained intact. If the fracture follows the weakest part of the growth plate between the hypertrophic and ossification zones, and the epiphyseal blood supply remains intact, the likelihood for growth disturbance is extremely low.[3]

Physis is described by Bright as a nonhomogeneous, anisotropic, viscoelastic substance. It reacts differently to physical stresses applied along different axes. The likelihood of disruption appears to be greatest with torsional loading and least with axial loading, with bending forces being intermediate.[4] The physis is more likely to absorb applied stresses than the surrounding soft tissue structures. This explains why physeal disruption will usually occur before the soft tissue. It is crucial to be aware that injuries that may cause ligament tears, tendon ruptures, or joint dislocations in adults are more likely to result in physeal fractures in children. Growth plate injuries are often mistaken for sprains. One should maintain a high index of suspicion with point tenderness near any physis.

There is a different growth rate with the proximal versus the distal epiphyses. The proximal growth plate has a much greater growth rate than the distal. This is important in terms of potential limb-length discrepancies from physeal injuries. It is less detrimental to sustain an ankle injury as opposed to a knee injury. There is also a differential growth rate within any individual physis. Any slight increase in compression will stimulate physeal growth. However, a larger increase in compression may retard physeal growth. This is the reason physiologic tibial and genu varum spontaneously correct itself by the slight increase in compression from an angular deformity.[5] It has been postulated that angular deformities of up to 30 degrees can be corrected spontaneously, if adequate growth remains and skeletal maturity has not been completed. In some situations it may be more prudent to accept a mild deformity rather than risk damaging the growth plate from forceful manipulation in an attempt for perfect reduction. Although angular deformities have a good chance of spontaneous reduction with growth, rotational deformities will not do so, and always require more aggressive anatomic realignment.

Rang demonstrated that physeal injuries in almost all parts of the body heal in approximately 3 weeks due to the marked increased inflammatory reaction. The dramatic inflammatory response may be responsible for growth stimulation frequently resulting in overgrowth following fractures. It is not unusual for children to have fevers as high as 40 degrees Celsius following major fractures.[6]

Approximately 15% to 20% of pediatric fractures involve growth plates, with distal physes of the extremities being the most prevalent. Tibia and fibula combined are second highest in frequency following the radius.[7] The peak incidence of physeal fractures is during adolescence. In girls, it is between the age of 8 and 13, and in boys, it is between the age of 12 and 16. The risk in boys is twice the risk in girls because of the greater exposure to trauma and the fact that the physes remain open longer. During puberty, the growth plate becomes much thicker, the periosteum and perichondrium become thinner, and the weight of the individual increases drastically. These all contribute to an increased susceptibility to mechanical failure. Since adolescent bones are near maturity, these fractures rarely result in significant leg-length discrepancy. These fractures, however, have less ability for spontaneous angular correction. All this further supports the importance of considering the age and type of deformity in determining the appropriate course of treatment.

EVALUATION AND CLASSIFICATION

In evaluating physeal fractures, radiography is still the most useful mode when used in conjunction with clinical presentation. It is important to get comparison views of the contralateral extremity when suspecting physeal fractures. CT scans are also valuable when radiographic findings are inconclusive or inconsistent with clinical findings. MRI is helpful in isolating or assessing suspected tendon or ligament injuries. The Salter-Harris classification system is still the most uniformly used system in the United States. This classification is mainly based on radiographic findings rather than the mechanism of injury.(Fig. 1) The fractures are classified into five types. Type I and II are extra-articular and often intra-periosteum. Type II is the most common type of physeal injury and appears to occur more frequently in children older than 10 years old. Type II injuries usually only require closed reduction for correction. Type III and IV are intra-articular in nature, thus carry a higher risk of complications and will often require open reduction for the realignment and restoration of the articular surface. These injuries in the lower extremity are most frequently found in the medial malleolus. When these fractures are vertical in nature, patients may end up with angular deformities. Transverse displacements, on the other hand, are more likely to result in growth arrests rather than in angular deformities. Type V injuries often result from an axial loading or depression type of mechanism.

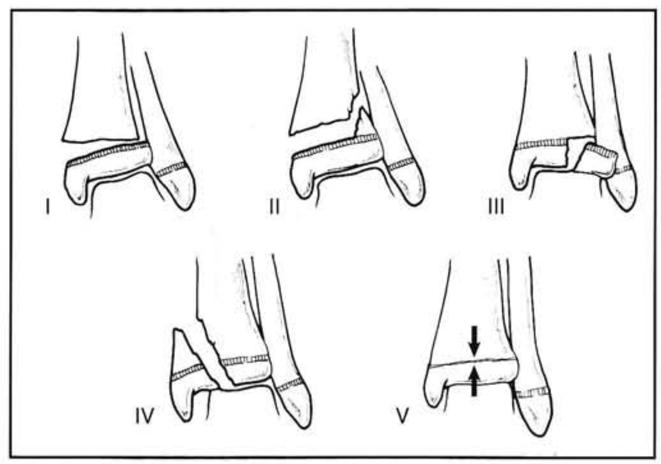

Figure 1. Salter-Harris classification: based on radiographic findings rather than mechanism of injury.

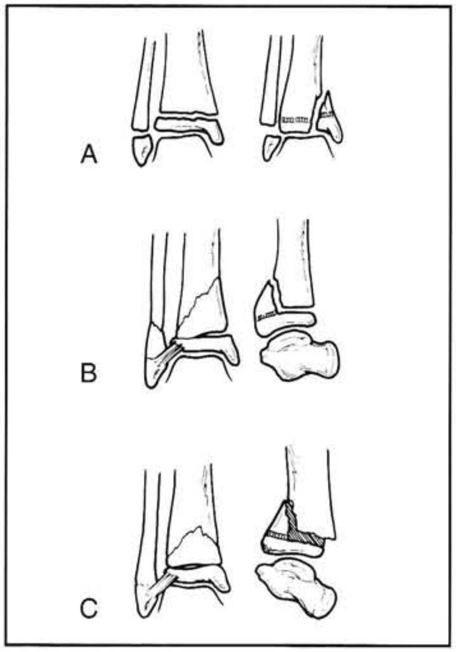

Figure 2. Dias-Tachdijian classification based on mechanism of injury: A, Supination-inversion or Supination-adduction. B, Supination-external rotation. C, Supination-plantarflexion.

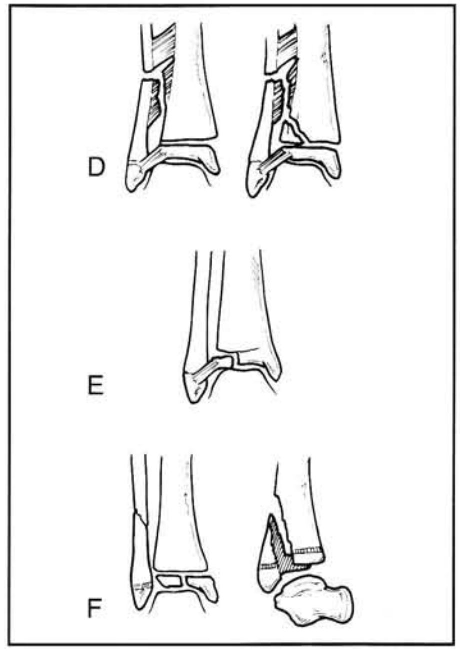

Figure 2. D, Pronation-eversion-external rotation. E, Juvenile Tillaux fracture. F, Triplane fracture.

PHYSEAL FRACTURES OF THE FOOT

Physeal fractures of the foot occur most frequently with the metatarsal and the phalanges. These injuries do not usually cause significant length disturbance or functional impairment because the foot grows only 0.9 cm in length per year after age 5.[8] The most important consideration with metatarsal head injuries is maintaining the anatomic alignment especially in the sagittal plane. Most of these fractures are correctable with closed reduction. If open reduction is necessary, one should try to preserve the capsular and periosteal blood supply to the metatarsal head.

PHYSEAL FRACTURES OF THE ANKLE

Physeal fractures of the ankle are usually of more concern due to the potential for more significant disability. Although Salter-Harris is the most commonly used system, it does not classify by the mechanism of injury. In the management of ankle fractures, determining the mechanism of injury can aid in the reduction process. With adults, we have the Lauge-Hansen classification system. The comparable system in pediatric ankle fractures is Dias-Tachdjian which was developed in 1978.(Fig. 2) Four major types of injuries described in this classification are supination inversion/adduction, supination-external rotation, supination-plantarflexion, and pronation-external rotation. There are also the juvenile Tillaux fracture and the triplane fracture which were originally described by Marmar in 1970.[9]

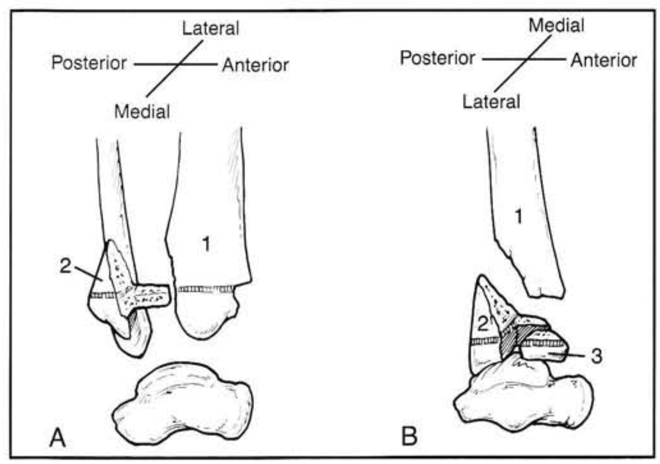

Figure 3. Two types of triplane fractures: A, Two-fragment fracture. B, Three-fragment fracture.

Triplane fractures are further differentiated into two-fragment and three-fragment fractures.(Fig. 3) Typically the metaphyseal portion is oriented in the coronal plane, the physeal portion in the transverse plane, and the epiphyseal portion in the sagittal plane. Based on our knowledge of anatomy and physiology of growth plates, we know that the closure of distal tibial physes occur sequentially in a specific pattern. The central medial portion is the first to close, followed by the posterior, and finally the anterolateral portion. The lateral plate usually remains open for 18 months after all the other portions of the physis have closed.[10] It is not surprising therefore to know that juvenile Tillaux fractures and triplane fractures often occur during puberty. These are considered transitional physeal fractures.

TREATMENT

The goals in treating pediatric ankle fractures are similar to the adult ankle fractures with some technical variations. Anatomic reduction with articular congruity will yield the best results. Closed reduction should be conducted as soon as possible when indicated. After several hours of swelling and hematoma formation, the task will become more challenging. Care must be taken for gentle reduction with the musculature as relaxed as possible to avoid grinding the fragments. Reduction in physeal fractures should be performed with 75% traction and 25% manipulation.[11] It is preferred to accept less than perfect reduction rather than to repeat multiple reduction attempts to avoid further injury. Surgical treatment is needed when the fracture involves articular surfaces, disrupts the proliferative layer, or is not responsive to closed reduction. It is recommended that internal fixation devices not be placed across the physis if all possible. If hardware must be placed across the physis, try to use smooth Kirschner wires of the smallest size possible. Following internal fixation, the patient should be non-weight bearing for 3 weeks. After this time, any hardware crossing the physis should be removed and cast immobilization should be continued for 3 more weeks. Physeal injuries should be evaluated every 3 months for the first year and then annually until maturity.

SUMMARY

It is essential to understand the dynamic physeal anatomy and physiology to properly manage growth plate fractures. Treatment of these fractures must be individualized without compromising the main principles of anatomic reduction and preservation of germinal cells. The ultimate goal for these patients is to maintain normal development without premature closure of growth plates.

REFERENCES:

1. Buddecke DE Jr, Mandracchia VJ, McGowan M, et al: Physeal fractures of the ankle. *Clin Pod Med Surg* 16:4, 1999.
2. Devalentine SJ: Epiphyseal injuries of the foot and ankle. *Clin Pod Med Surg* 4:1, 1987.
3. Salter RB: Injuries involving the epiphyseal plate. *J Bone Joint Surg*, 45(A):587, 1963.
4. Bright RW, Burstein AH, Elmore SM: Epiphyseal-plate cartilage. *J Bone Joint Surg*, 56(A):688-703, 1974.
5. Rockwood C: *Fractures in Children*. J.B. Lippincott, Philadelphia, 1984.
6. Rang M: Injuries of the epiphysis, growth plate, and perichondral ring. *Children's Fractures*. JB Lippincott, Philadelphia pp10-25, 1983.
7. Rogers LF: The radiography of epiphyseal injuries. *Radiology*, 96:289-299, 1970.
8. Blais MM, Green WT, Anderson M: Lengths of the growing foot. *J Bone Joint Surg*, 38(A):998-100, 1956.
9. Marmor L: An unusual fracture of the tibial epiphysis. *Clin Orthop*, 73:132-135, 1970.
10. Kleiger B, Mankin HJ: Fracture of the lateral portion of the distal tibial epiphysis. *J Bone Joint Surg Am* 46:25-32, 1964.
11. Hresko MT, Kasser JS: Physeal arrest about the knee associated with nonphyseal fractures in the lower extremity. *J Bone Joint Surg Am* 71:1756, 1993.