Review of Distal Tibial Epiphyseal Transitional Fractures

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Abstract: The closure of the distal tibial physis occurs over an 18-month period between ages 12 and 15 years. During this time period, children are susceptible to several transitional fractures, so labeled because they are transitioning to skeletal maturity. In the setting of an external rotation force, triplane and Tillaux fractures can occur. These fractures, which present similarly to other Salter-Harris growth plate injuries, do not fit neatly into any 1 classification scheme and are not easily evaluated on plain radiographs. Computed tomography scans are required to optimally assess these fractures and to determine the need for closed vs open treatment. Regardless of which treatment modality is chosen, anatomic reduction is the goal. This article discusses the approach to these unique fractures.

Pediatric ankle fractures make up approximately 5% of all pediatric fractures and are the third most common physeal injury, after finger and distal radial physeal fractures. Peak incidence is at 8 to 15 years, with boys twice as susceptible as girls. Similar to adults, these fractures occur during sports and other activities requiring pivoting movements and rapid changes in direction. However, these mechanisms of injury often lead to different injuries in each population. In pediatric ankle fractures, ligamentous damage is rarely encountered because ligaments are stronger than an open physis. As such, physeal fractures occur in these patients, whereas an adult might sustain a purely ligamentous injury after sustaining similar low-energy trauma (eg, inversion injury).

Most pediatric ankle fractures are classified by anatomic location or the mechanism of injury, with the Salter-Harris classification the most common. In this scheme, fracture classification is based on physeal involvement. The Dias-Tachdjian classification relies on the mechanism of injury, specifically foot position at the time of injury and the direction of the force. Despite the popularity of these classification schemes, 2 transitional pediatric ankle fractures evade simple categorization: pediatric triplane and juvenile Tillaux fractures, which will be discussed in this article.

Historical Perspective

Johnson and Fahl are credited with first reporting what is known as the triplane fracture in 1957. In 1970, Marmor elucidated the complexity of these distal tibial epiphyseal injuries in his discussion of an ankle fracture requiring open treatment in a 12-year-old girl. He described a fracture with 3 fragments: an anterolateral epiphyseal fragment, the remaining epiphysis with an attached posterior metaphyseal spike, and the distal tibial shaft. In 1972, Lynn described similar distal tibial epiphyseal injuries in 2 children, referring to them as triplane fractures because of their transverse, coronal, and sagittal plane fracture lines.

The juvenile Tillaux fracture was described by Kleiger and Mankin in 1964. It refers to an...
The distal tibial physis contributes 50% of tibial growth and approximately 0.25 inches (4-6 mm) of longitudinal growth per year.\textsuperscript{11,12} Triplane fractures occur in children aged 12 to 15 years as they progress toward skeletal maturity. During this time, an 18-month period occurs in which the distal tibial epiphysis undergoes asymmetric closure. Closure begins centrally and then proceeds in an anteromedial direction, then posteromedial, and finally to the lateral aspect of the epiphysis (Figure 1). It is important to note that these transitional fractures rarely occur in patients younger than 10 years or older than 16.7 years.\textsuperscript{13} However, anytime the lateral distal tibial physis is open, the patient is susceptible to a triplane fracture (Figure 2A).

A triplane fracture behaves like a Salter-Harris IV fracture and consists of sagittal, transverse, and coronal components that traverse the physis, entering the ankle joint.\textsuperscript{14,15} Most fractures are attributed to an external rotation force of the foot on the leg. However, other mechanisms have been described.\textsuperscript{16}

Triplane fractures are classified as 2-, 3-, or 4-part. The fibula can be fractured in conjunction with any type of triplane fracture. In a 2-part fracture, 3 fracture lines are identified in the transverse, coronal, and sagittal planes. The fracture line in the transverse plane is through the physeal plate, leaving the anteromedial physeal plate attached to the distal tibia (Figure 2B). The sagittal plane fracture line traverses the epiphysis, and the coronal plane fracture travels superiorly through the posterior metaphysis (Figures 2C, D). This leads to 2 fracture fragments, 1 comprising the posteromedial and lateral portions of the epiphysis with a posterior metaphyseal spike and the other comprising the distal tibia with the anteromedial epiphysis attached.

The 3-part fracture also possesses fracture lines in each plane. However, the coronal plane fracture line traverses the epiphysis and posterior metaphysis in their entirety. The 3 fracture fragments that result are a rectangular fragment of the anterolateral portion of the epiphysis, the remainder of the epiphysis with an attached posterior spike of the distal tibial metaphysis, and the tibial shaft with the proximal metaphysis and anteromedial epiphysis. When the fracture extends more medially in the transverse plane, a 4-part fracture develops as a fourth fragment comprising the medial malleolus is created.

Juvenile Tillaux fractures occur in adolescents within 1 year of complete distal tibial physeal closure. At this time, only the anterolateral aspect of the physis is open and vulnerable to injury. With an external rotation force on the foot, a rectangular or pie-shaped piece of the anterolateral portion of the distal tibial epiphysis may be broken off, leading to a Salter-Harris III fracture (Figure 3).

**Figure 2:** Axial computed tomography scan through the physis showing a triplane fracture with the posteriolateral portion of the tibia hinged open on the partially closed medial physis (A). Coronal computed tomography scan showing the anterolateral epiphyseal fragment attached to the posterior metaphyseal spike (Salter III fracture pattern) (B). Sagittal computed tomography scan at the level of the fracture seen in Figure 2B. This has the appearance of a Salter II fracture pattern (C). Sagittal computed tomography scan 1 slice medial to Figure 2C showing the closed physis and intact anteriomendial fragment attached to the distal tibia. If the physis were open, this would be a Salter IV fracture pattern (D).

**DIAGNOSIS**

Most patients are adolescent boys with right ankle involvement.\textsuperscript{17} This is attributed to the later closure of the lateral distal tibial physis in boys compared with girls, making them more vulnerable to this injury for a greater amount of time. The history will provide valuable information because the majority of triplane and Tillaux fractures involve an external rotation mechanism.\textsuperscript{19}

Diagnostic imaging is an essential component of the workup of pediatric ankle fractures. Plain radiographs should be obtained first and should include anteroposterior (AP), lateral, and mortise views of the ankle.\textsuperscript{18} The triplane fracture appears as a Salter-Harris type III fracture on AP radiographs and as a Salter-Harris type II fracture on lateral radiographs (Figure 4). The juvenile Tillaux fracture appears as a Salter-Harris III on AP and lateral radiographs.

A computed tomography (CT) scan should be obtained because the practitioner may...
fail to appreciate the true extent of the fracture on standard radiographs. It is also useful for delineating the fracture fragments and for preoperative planning.\textsuperscript{19,20} In a cadaver model of juvenile Tillaux fractures, Horn et al\textsuperscript{21} compared CT scans with radiographs. Although CT scans and radiographs were found to be accurate to within 1 mm 50\% of the time, the authors found that CT scans are more sensitive in detecting fracture displacements larger than 2 mm.\textsuperscript{21} In addition, Kim et al\textsuperscript{22} found that a better understanding of fracture configuration, such as that provided by CT, correlated with improved outcomes with triplane and Tillaux fractures.

The role of magnetic resonance imaging (MRI) remains unclear.\textsuperscript{18} At this time, its limited indications in the setting of triplane and juvenile Tillaux fractures include the evaluation of complex ankle injuries that are difficult to classify based on other imaging modalities, ruling out ligamentous injury or osteochondral fractures, evaluation of occult fractures, and identification of premature physeal closure and sources of unrelenting pain following fracture treatment.\textsuperscript{18,23}

**TREATMENT**

Open and closed techniques have been successfully used to treat triplane and juvenile Tillaux fractures of the distal tibia. When selecting a therapeutic modality, orthopedic surgeons must remember that these are intra-articular injuries involving the growth plate. As such, failure to achieve anatomic reduction can lead to posttraumatic degenerative arthritis and occasionally premature physeal closure.\textsuperscript{23}

Minimally displaced (less than 2 mm of displacement) and extra-articular fractures are amenable to immobilization in a long-leg cast, with satisfactory outcomes well documented in the literature.\textsuperscript{24} When between 2 and 3 mm of displacement is present, closed reduction should be performed under procedural sedation or general anesthesia. With the foot in plantar flexion, reduction is achieved with traction and internal rotation. The only exception is with medial fractures in which external rotation facilitates reduction. The triplane or juvenile Tillaux fracture that is managed nonoperatively should undergo a post-reduction CT scan to assess the reduction and serial radiographs to ensure that the reduction is maintained and to follow the progression of physeal closure. Fracture displacements larger than 3 mm require open reduction and internal fixation, as do fractures that continue to have more than 2 mm of articular step-off following attempted closed reduction. In these instances, poor outcomes have been consistently observed with closed treatment and are attributed to the energy of the injury and soft tissue interposition at the fracture.\textsuperscript{1,25}

In some cases, closed reduction and percutaneous screw fixation can be used (Figure 5). An open anterolateral approach is used for lateral fractures, and an anteromedial approach is used for medial injuries, with additional incisions (eg, posterolateral) made as needed to enhance exposure (Figure 6). Arthroscopic techniques have also been described for the treatment of these fractures.\textsuperscript{26,27}

In the setting of a concurrent fibula fracture, closed and open reduction of triplane and Tillaux fractures can be challenging, and at times impossible. In this setting, the fibula fracture should be reduced and stabilized first, followed by reduction and fixation of the distal tibial epiphyseal fracture.

**Complications**

Residual articular incongruity and the development of degenerative arthritis are the predominant concerns with inadequately reduced transitional fractures of the distal tibial epiphysis. Although physeal arrest is often considered the most severe sequelae of a transphyseal injury, triplane and Tillaux fractures are less likely to result in premature physeal closure compared with other pediatric ankle fractures because the patients who sustain these injuries are close to skeletal maturity.\textsuperscript{28}

Tillaux fractures have the lowest rates of growth arrest because they occur in an older age group than any of the traditional Salter-Harris–type fractures and the triplane fracture. Rates of

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**Figure 3:** Coronal (A) and sagittal (B) computed tomography scans of a 13-year-old girl who presented with right ankle pain and swelling following a rollerskating accident. Salter-Harris III injuries are seen on both cuts, consistent with a Tillaux fracture. Note that although the same age as the boy in Figure 1, this girl sustained an injury seen closer to complete physeal closure. This is consistent with normal physiology and skeletal growth in that girls reach skeletal maturity before boys.

**Figure 4:** Mortise (A) and lateral (B) radiographs of the patient in Figure 2 showing the appearance of a Salter III fracture on the mortise view and Salter II fracture on the lateral view.
CONCLUSION

Pediatric triplane and juvenile Tillaux ankle fractures represent transitional injuries occurring in individuals approaching skeletal maturity. They do not fit neatly into the Salter-Harris classification and must be viewed as atypical and uncommon pediatric fractures. Both fracture types occur via an external rotational force. However, triplane fractures can have multiple configurations consisting of 2, 3, and 4 parts.

Plain radiographs can help guide clinical decision making, but CT scans will be of the most use to orthopedic surgeons. Closed and open treatment modalities exist, with fractures with more than 3 mm of displacement always necessitating open reduction. Anatomic restoration of the distal tibia is crucial because this will most significantly reduce the risk of these patients developing degenerative arthritis of the ankle.

REFERENCES


Figure 5: Postoperative mortise (A) and lateral (B) radiographs of the patient seen in Figures 2 and 4. The fracture was reduced with traction and internal rotation. Two anterior-to-posterior lag screws were percutaneously placed into the metaphyseal spike, and a third medial to lateral screw was used to lag the Salter III component.

Figure 6: Intraoperative fluoroscopy showing fixation of the Tillaux fracture shown in Figure 3. An anterolateral approach was used, with definitive fixation via a 4-0 cancellous screw.