



# Ankle fractures in children

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- Ankle fractures are common in children, and they have specific implications in that patient population due to frequent involvement of the physis in a bone that has growth potential and unique biomechanical properties.
- Characteristic patterns are typically evident in relation to the state of osseous development of the segment, and to an extent these are age-dependent.
- In a specific type known as transitional fractures – which occur in children who are progressing to a mature skeleton – a partial physal closure is evident, which produces multi-planar fracture patterns.
- Computed tomography should be routine in injuries with joint involvement, both to assess the level of displacement and to facilitate informed surgical planning.
- The therapeutic objectives should be to achieve an adequate functional axis of the ankle without articular gaps, and to protect the physis in order to avoid growth alterations.
- Conservative management can be utilized for non-displaced fractures in conjunction with strict radiological monitoring, but surgery should be considered for fractures involving substantial physal or joint displacement, in order to achieve the therapeutic goals.

**Keywords:** paediatric ankle; physal ankle fracture; Salter-Harris fractures of the tibia

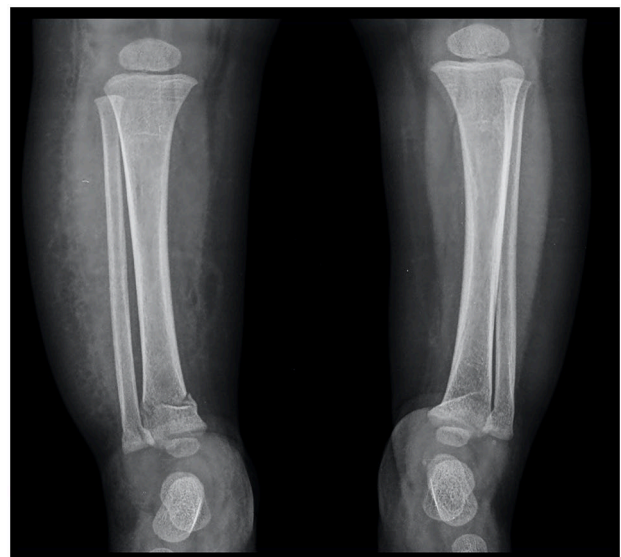
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## Introduction

The tibia, fibula, and wider distal metaphyseal region of a child's ankle have a series of unique compositional and physiological characteristics associated with developing bone tissue that result in specific morphological fracture patterns.<sup>1</sup> Ankle fractures account for approximately 5.5% of fractures in paediatric patients, and 15% of physal injuries.<sup>2</sup> They are twice as common in boys than in girls.<sup>1</sup> Their highest incidence is between the ages of eight and 15 years, and most are associated with sports activities.<sup>2</sup> One of the primary treatment objectives is re-establishing

joint congruence and functional alignment in order to avoid osteoarthritis. The other is protecting the physis in order to avoid deformities or length differences following growth progression,<sup>3</sup> given that the distal tibial physis constitutes approximately 45% of the ankle's length.<sup>4</sup> The distal tibial physis is the third most common site of physal injury (approximately 11%).<sup>2</sup>

Care must be taken when verifying that the medical history is concordant with the findings of the physical examination. In the case of a history of pain and limping, differential diagnoses such as musculoskeletal infection, bone tumour, and rheumatologic or haematologic diseases should be ruled out. Traumatic injuries prior to the start of the gait (Fig. 1) or avulsive injuries of the metaphyseal corners of the tibia are highly suggestive of non-accidental injury, so appropriate investigative protocols must be followed in such situations.<sup>5</sup>



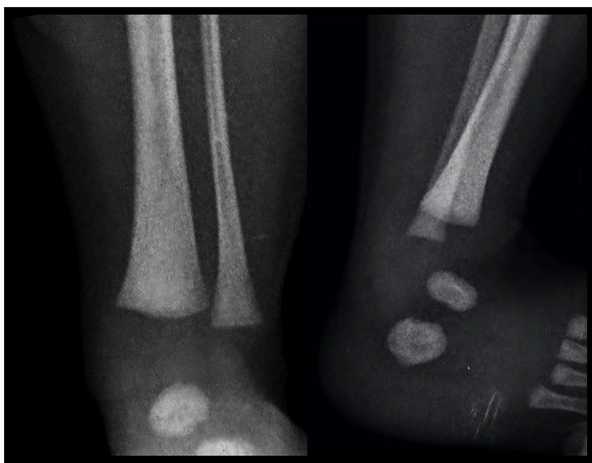
**Fig. 1** X-rays of both legs of an eight-month-old boy. Bilateral metaphyseal impaction is evident. Investigation in accordance with a standard protocol suggested that the injuries were non-accidental.

## Anatomy

The ankle joint is made up of the distal portions of the tibia and the fibula, which form a mortise where the superior aspect of the talus articulates, stabilized by the ligament complexes of the tibiofibular syndesmosis (anteroinferior tibiofibular, posteroinferior tibiofibular, and interosseous tibiofibular ligaments), collateral medial ligaments (superficial and deep components), and collateral lateral ligaments (anterior talofibular, calcaneofibular, and posterior talofibular ligament). It is a synovial hinge-type load-bearing joint with movement on a single axis, allowing dorsiflexion and plantar flexion.<sup>6</sup>

In neonates the distal physes of the tibia and fibula are transverse, such that the fibular physis is distal to the tibial physis, and is located at the level of the distal tibial epiphysis (Fig. 2). The secondary ossification centre of the distal tibia appears during the first year of life, and is located centrally and homogeneously distributed until the tibial plafond is ossified, resulting in a wedge towards the lateral aspect (Fig. 3). Between two and three years of age the secondary ossification centre of the fibula is established, and its physis is located at the level of the articular surface of the tibia. Undulations are present in both physes, and anteromedial undulation in the tibia is characteristic (Fig. 4).<sup>7</sup> Ossification towards the medial malleolus becomes radiologically evident at approximately the age of 6–7 years, in parallel with ossification of the distal portion of the secondary ossification centre of the fibula (Fig. 5).<sup>8</sup>

At approximately 8 to 10 years of age medial malleolus ossification is completed. This process can have, in up to 20% of cases, an accessory ossification centre. In addition, the trabecular structure of the distal tibial epiphysis is adapted to the load distribution zones of the tibial plafond. Distal tibia ossification and closure of its



**Fig. 2** X-rays of a newborn's left ankle. Physis is evident transversely in the tibia and fibula, the latter being more distal, at the level of the tibial epiphysis.



**Fig. 3** X-rays of a 12-month-old boy's right ankle. Secondary ossification nuclei are present in the distal epiphyses of the tibia and fibula.



**Fig. 4** X-rays of a three-year-old girl's right ankle. Anteromedial undulation of the tibial physis is evident, and the fibular physis reaches the tibial articular surface.



**Fig. 5** X-rays of a seven-year-old girl's left ankle. The beginning of ossification of the medial malleolus is evident, as is distal ossification of the lateral malleolus.

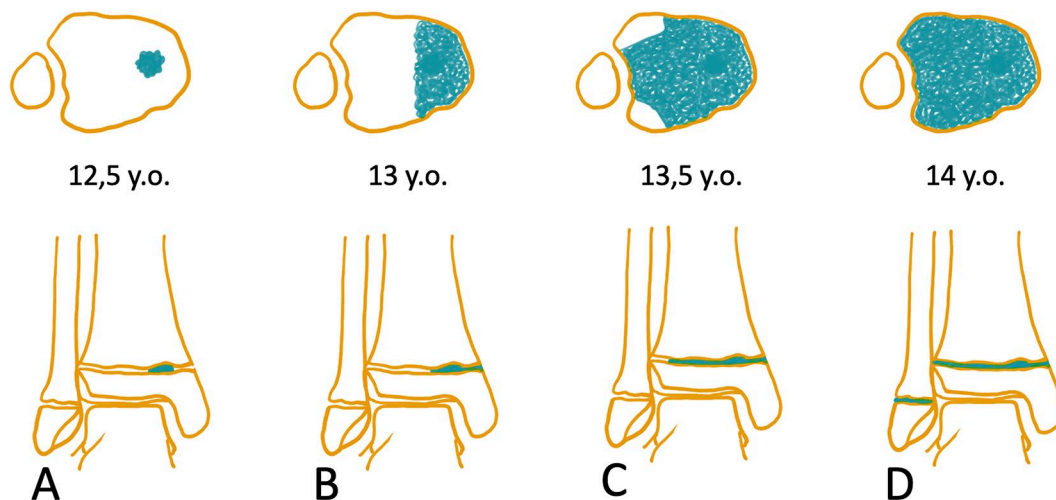
physis begin from the anteromedial area, before the start of fibular physeal closure. Prior to its closure an undulation forms in the anteromedial area of the distal tibial physis called 'Poland's hump' (Fig. 6), from where closure progresses first medially, then posteriorly, then laterally, then lastly anterolaterally (Fig. 7).<sup>9</sup> This growth pattern has been confirmed via magnetic resonance imaging (MRI),<sup>10</sup> in which it is evident that in girls physeal closure begins between the ages of 11 and 12 years, and in boys it begins between the ages of 12 and 13 years. Ossification of the distal tibial epiphysis lasts an average of 18 months, and is complete by the age of 14 or 15 years.<sup>11</sup> Physeal closure can begin much earlier than this, however, and MRI indicates that complete closure occurs much later.<sup>12</sup> The growth provided by the distal physis corresponds

to approximately 45% of the length of the tibia, and the growth provided by the distal physis of the fibula corresponds to approximately 40% of the length of the fibula, completing its physical closure together with the closure of the lateral portion of the distal tibial physis.<sup>13</sup>

The age at which a traumatic injury occurs influences the fracture patterns involved, and the developmental stage of the ankle's anatomy and the extent of physeal closure are of particular relevance. Children aged < 10 years tend to exhibit a compression pattern and metaphyseal arching (Fig. 8), and those aged approximately 10 years tend to exhibit malleolus lesions. Physeal lesions are commonly evident in older children, and in adolescents at the end of the growth period so-called transitional fractures (triplanar and juvenile Tillaux) are typical.<sup>14</sup>



**Fig. 6** X-rays of the right ankle of an 11-year-old boy. The beginning of physeal closure is visible at the level of Poland's hump.



**Fig. 7** Sequence of distal physeal closure of the tibia. Closure begins from the anteromedial area (A), then progresses medially (B), posteriorly (C), and laterally (D).



**Fig. 8** X-rays of the left ankle of a 10-year-old girl with a metaphyseal bending fracture (arrows).

### Diagnosis

Oedema and/or ecchymosis are usually evident in the skin upon physical examination. The skin must be thoroughly examined to rule out an open fracture. Significant bone displacement can cause obvious deformity and even impair foot circulation. A thorough neurovascular evaluation should always be performed. The points of maximum sensitivity to palpation may be key to understanding the injury, and the presence of pain in the bony prominences may indicate a lesion of the physis.<sup>3</sup>

In children, compartment syndrome is rare after an ankle fracture, but it must always be formally ruled out due to its severity, potential sequelae, and associated need for urgent resolution. The potential presence of severe pain that increases with passive movement should be investigated, as should severe oedema and even sensory disturbances.<sup>15</sup> The ‘three ‘A’s’ should be looked for: anxiety, agitation, and an increasing need for analgesia.

Extensor retinaculum syndrome may exist in a low percentage of patients in whom excessive displacement of fracture fragments causes compression of the structures of the anterior aspect of the ankle, particularly the deep peroneal nerve. Hypoesthesia or anaesthesia may be evident in the region of the big toe, and there may be weakness of the extensor hallucis longus and common extensor digitorum, and pain on passive flexion of the toes, mainly the first toe.<sup>16</sup> The syndrome must be resolved as a matter of urgency, in conjunction with simultaneous surgical fracture reduction.

In cases of suspected ankle fracture several criteria can be used to reduce the use of radiography, of which the ‘Low Risk Ankle Rules’<sup>17</sup> and the Ottawa criteria<sup>18</sup> have been investigated in children. The former are reportedly not sensitive enough for widespread use, whereas the Ottawa criteria have exhibited 100% sensitivity for the diagnosis of substantial injuries.<sup>19,20</sup> Notably, however,

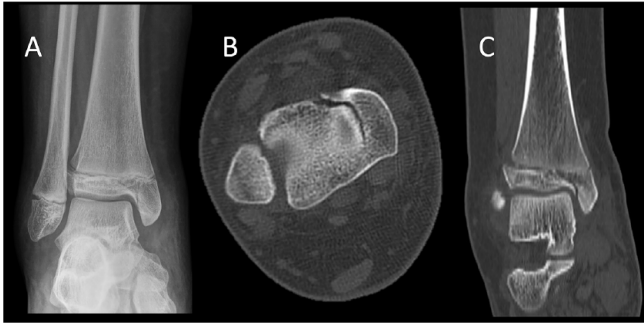
variations in clinical presentations and responses to pain in children usually lead to radiography being performed, including that encompassing standard anteroposterior and lateral views of the ankle, in addition to the mortise view.<sup>1</sup> The latter is particularly useful for identifying fission or intra-articular lesions with little displacement.<sup>15</sup>

Some considerations must be borne in mind when evaluating radiographs. In children in whom secondary ossification nuclei are not yet evident, radiography should be repeated after two weeks in cases in which there is a strong suspicion of a broken ankle; because in some cases initial images may be normal despite subsequent images depicting periosteal thickening confirming an injury. The presence of Park–Harris lines can also be investigated. Where present these lines correspond to transverse rings of sclerosis, are parallel to the physis, and are caused by transitory calcification of the physiological cartilage (Fig. 9). They should be parallel to the physis during normal growth, and their alteration indicates physeal damage.<sup>1</sup> Lastly, assessors require adequate knowledge of normal anatomical development in order to avoid erroneously interpreting normal findings such as the presence of Poland’s hump or accessory ossification nuclei as indicative of traumatic bone injury.

Computed tomography (CT) is indicated in cases of injuries that compromise the articular surface (Fig. 10), in which it can provide useful information pertaining to indications for surgery as well as surgical planning,<sup>3,21</sup> especially in triplanar and juvenile Tillaux injuries.<sup>22</sup> The radiation exposure associated with these CT examinations is comparatively low, and is considered equivalent to the radiation dose associated with 0.9 chest radiographs.<sup>23</sup> Accordingly its utility is high in applicable cases.<sup>24</sup>



**Fig. 9** X-rays of the right ankle of a 10-year-old girl. Park–Harris lines (arrows) that are parallel to the physis are visible, indicating normal growth.



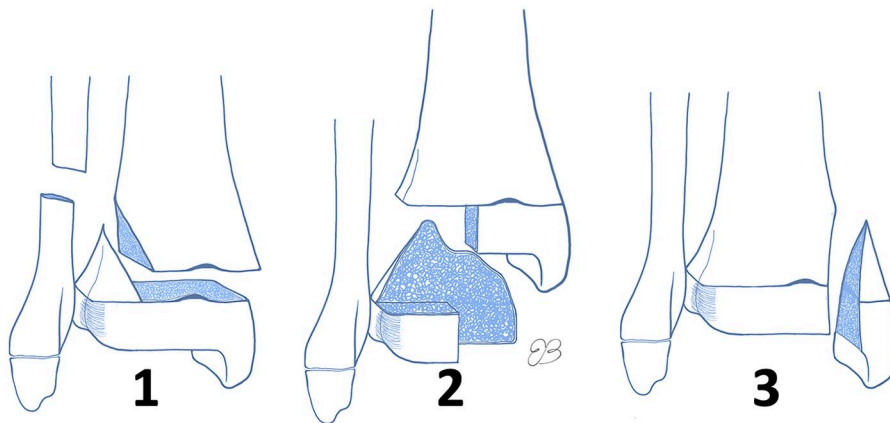
**Fig. 10** Radiography (A) and computed tomography (B, C) of the right ankle of an 11-year-old girl with a Salter–Harris type III fracture with joint involvement.

The role of MRI remains uncertain, and it does not have a substantial influence on therapeutic decisions.<sup>25</sup> It can reveal hidden fractures, and it can be used to assess premature physis closure and injury of the articular cartilage, ligaments, and tendons. It can also be used to identify the cause of persistent pain after a fracture has consolidated.<sup>15,26</sup>

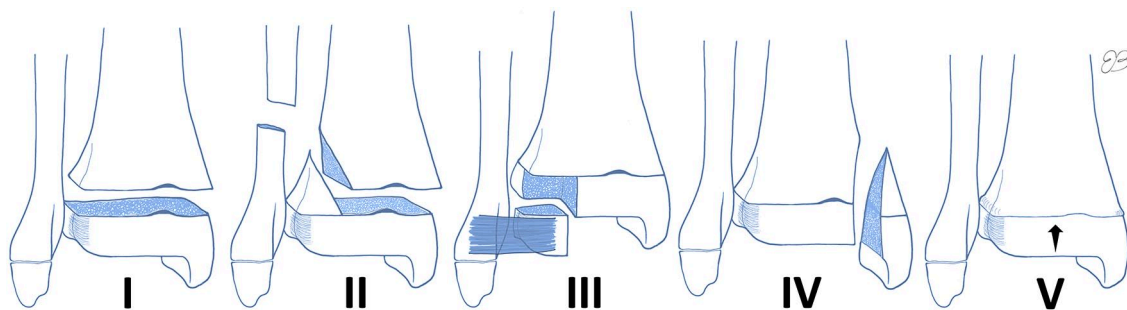
## Classification

Johnson and Fahl<sup>27</sup> developed the first classification system for paediatric ankle fractures in 1957, dividing them into three main groups (Fig. 11). For injuries that affect the physis, the 1963 Salter–Harris classification system (Fig. 12) is the most widely used for all segments because it is simple and provides a prognosis based on the pattern of injury.<sup>28</sup> In that system type I fractures extend through the growth plate without involving the metaphysis or epiphysis, type II fractures extend through the physis and metaphysis, and type III fractures involve the physis and epiphysis. Type IV fractures involve the metaphysis, physis, and epiphysis, and type V fractures involve physeal compression. The risk of physeal arrest is lower in patients with type I and II injuries than in those with type III, IV, and V injuries. Types III–V usually require reduction and internal fixation, which reduces joint surface inconsistency and reduces the risk of physeal bar formation.<sup>29,30</sup>

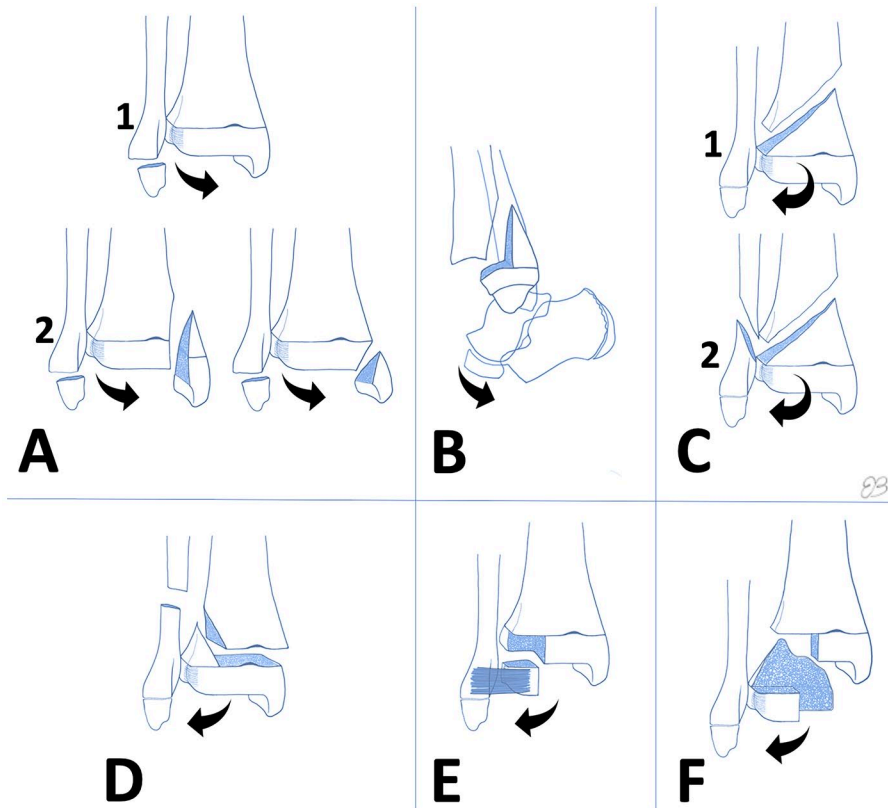
In 1978, Dias and Tachdjian<sup>31</sup> published their own classification system for ankle fractures in paediatric patients (Fig. 13), which is based on the Lauge-Hansen and



**Fig. 11** Johnson and Fahl classification: 1, abduction type; 2, plantar flexion type; 3, adduction type.<sup>27</sup>



**Fig. 12** Salter–Harris classification: type I, complete separation of the epiphysis from the metaphysis through the physis; type II, fracture line along the physis and a portion of metaphysis; type III, fracture line along the physis and a portion of epiphysis; type IV, fracture line through epiphysis, physis and metaphysis; type V, crushing force through the epiphysis to the physis.<sup>28</sup>



**Fig. 13** Dias-Tachdjian classification: (A) supination-inversion; (B) supination-plantar flexion; (C) supination-external rotation; (D) pronation-eversion; (E) Salter–Harris III of distal tibial epiphysis; (F) triplane fracture.<sup>31</sup>

Salter–Harris principles. The six Dias-Tachdjian types are supination-inversion, supination-plantar flexion, supination-external rotation, pronation-eversion, Salter–Harris III distal tibia epiphysis, and triplane fracture. The first term indicates the position of the foot at the time of the fracture, and the second refers to the direction of force at the time of the injury; with the exception of the transitional fractures E and F, which have unique features.<sup>15</sup> Transitional fractures occur during the 18 months in which physical closure of the distal tibia occurs, and there are two specific types: triplanar fractures and juvenile Tillaux fractures.<sup>32</sup>

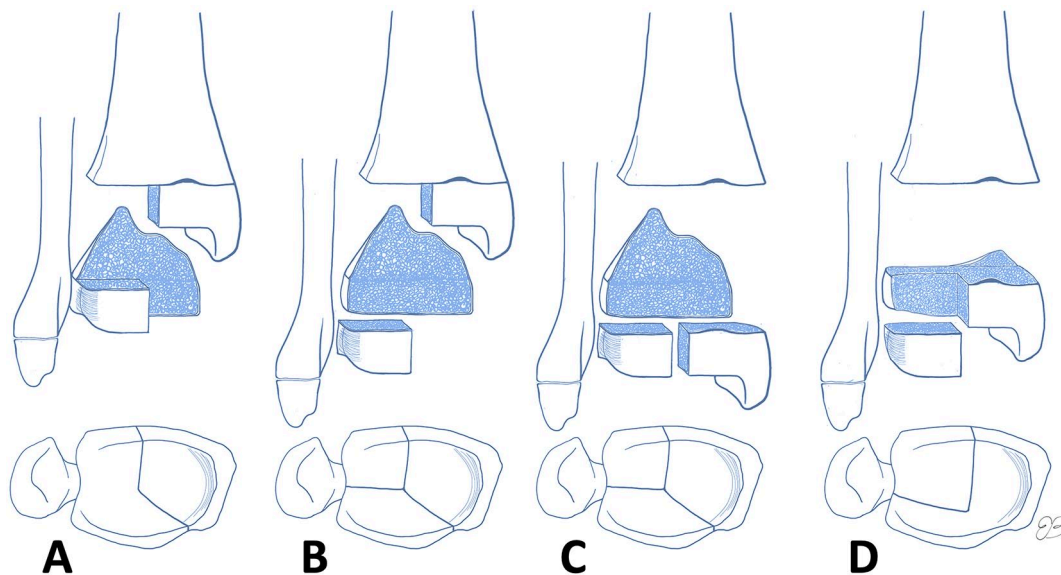
In triplanar fractures, the fracture line involves the coronal, transverse, and sagittal planes. In the transverse plane there is a physal fracture line, in the coronal plane there is a metaphyseal fracture line, and in the sagittal plane there is an epiphyseal fracture line.<sup>26</sup> Such injuries were described in 1957 by Johnson and Fahl<sup>27</sup> in their classifications of ankle fractures in children, and they were named ‘triplanar fractures’ by Lynn<sup>33</sup> in 1972. They reportedly account for 4–10% of ankle fractures in children, and 7–20% of all fractures of the distal tibial physis.<sup>26</sup> The most common ages at presentation are 11–12 years in girls and 13–14 years in boys, which correspond with pubertal growth spurts and the beginning

of closure of the distal tibial physis. The younger the patient the more medial the epiphyseal component tends to be. It is the product of a torsional mechanism of the ankle in conjunction with the presence of physal closure at the level of Poland’s hump, where the medial portion of the physis stabilizes, causing a sagittal fracture at the epiphyseal level. Its classic presentation consists of an intra-articular epiphyseal sagittal fracture line lateral to Poland’s hump, accompanied by a posterolateral metaphyseal coronal fracture line, connected by a transverse fracture through the physis (Fig. 14). This pattern is highly variable, resulting in different presentations in relation to the epiphyseal fragment<sup>34</sup> – lateral epiphyseal in two parts, lateral epiphyseal in three parts, lateral epiphyseal in four parts, and medial epiphyseal in three parts (Fig. 15). Extra-articular epiphyseal patterns have also been described (Fig. 16), in which the fracture lines pass through the medial malleolus (Fig. 17).<sup>35</sup>

In a cadaveric study reported in 1892, Paul Jules Tillaux<sup>36</sup> described isolated avulsion of the lateral margin of the distal tibia caused by a forced abduction mechanism, with no mention of the presence of a physis. He also described a triangular lateral fragment that differed from that typically evident in adolescents. The term ‘juvenile



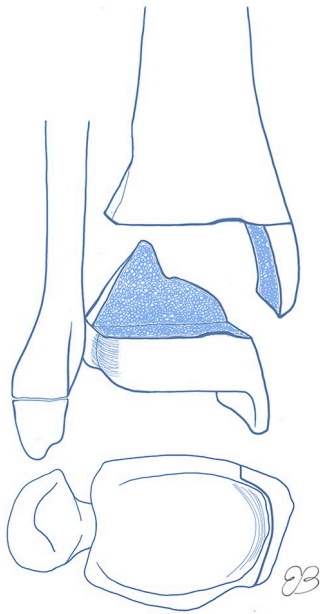
**Fig. 14** Computed tomography of the left ankle of a 12-year-old boy with a classic pattern triplane fracture. Epiphyseal fracture is visible in the coronal section and in the distal axial section (A, B). Metaphyseal fracture is visible in the proximal axial section and in the sagittal section (C, D). Physeal compromise is evident in the coronal and sagittal sections (A, D).



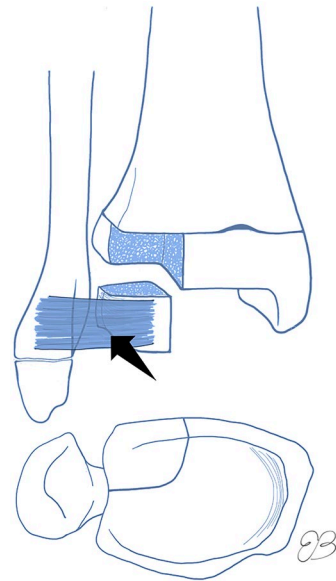
**Fig. 15** Triplanar fracture patterns. Lateral epiphyseal in two parts (A), lateral epiphyseal in three parts (B), lateral epiphyseal in four parts (C), and medial epiphyseal in three parts (D).

Tillaux' arose from this description, and refers to fracture of the anterior distal tubercle of the tibia in adolescents. Such fractures account for 3–5% of ankle fractures in children.<sup>15</sup> The usual age of presentation of these injuries is between 11 and 15 years, and the most common age at which they occur is 13 years. They are more frequent in girls, with a ratio of 2:1.<sup>32</sup> Juvenile Tillaux injuries are the product of a mechanism of abduction and forced external rotation of the foot, or internal rotation of the tibia with the

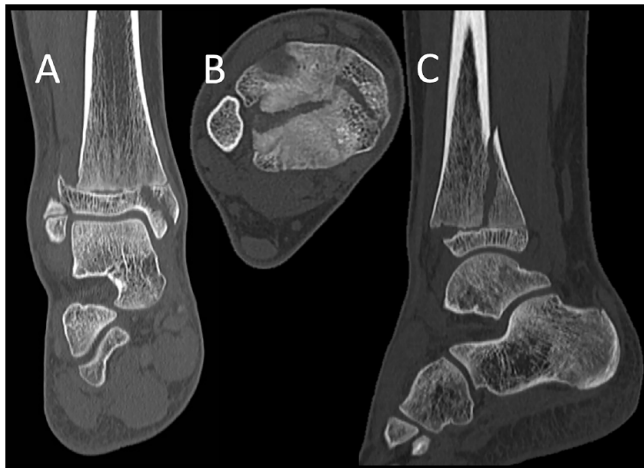
foot fixed. In such situations the fibula is transferred posteriorly, causing tension of the anterior tibiofibular ligament and provoking avulsion of the distal anterior tubercle of the tibia, which is susceptible to fracture because it is narrower in the anteroposterior plane (Fig. 18). The lesion occurs in adolescence, after the medial portion of the distal physis of the tibia is closed. It consists of a Salter–Harris III fracture type, with a horizontal fracture line in the physis and a vertical fracture line in the epiphysis, creating a



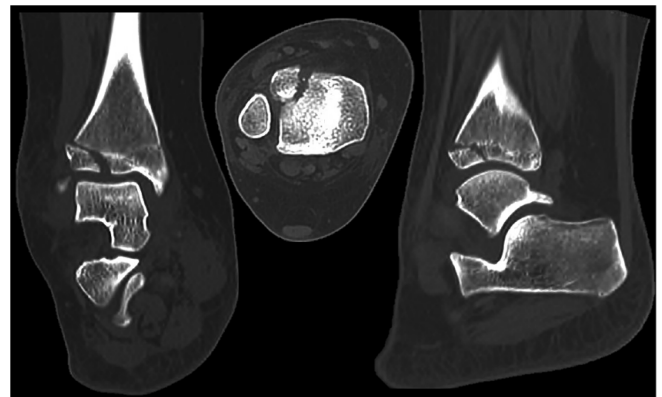
**Fig. 16** Extra-articular triplanar fracture pattern.



**Fig. 18** Juvenile Tillaux fracture pattern. The anterior tibiofibular ligament is inserted into the avulsed fragment of the anterior distal tubercle of the tibia (arrow).



**Fig. 17** Computed tomography of the left ankle of a 13-year-old girl with an extra-articular triplanar fracture. A sagittal fracture that compromises the medial malleolus is visible in the coronal (A) and axial sections (B), and a coronal metaphyseal pattern is evident in the sagittal section (C).



**Fig. 19** Computed tomography of the right ankle of a 15-year-old boy depicting a juvenile Tillaux fracture. A square-shaped fragment is observed in all sections.

square bone fragment (Fig. 19). In cases that occur closer to the end of growth a Salter-Harris IV pattern may be evident, with a small lateral triangular metaphyseal fragment, similar to an adult Tillaux lesion.<sup>32</sup>

### Treatment

Regardless of their classification, non-displaced fractures require conservative treatment, including immobilization of the segment and discharge with two crutches,

unless there is rotation of the segment. We recommend radiological examination at 7–10 days to rule out late displacement, especially in high-energy mechanism fractures. Immobilization is usually maintained for 4–6 weeks depending on the age of the patient and the type of fracture, followed by load as tolerated for two weeks.<sup>32,37</sup> Boutis et al<sup>38</sup> concluded that a removable ankle immobilizer is more effective than a short leg cast in terms of functional recovery, and is associated with an earlier return to normal activities and a greater degree of patient acceptance, as well as being cost-efficient.

Fractures involving displacement at the physeal or joint level may require management by closed reduction.



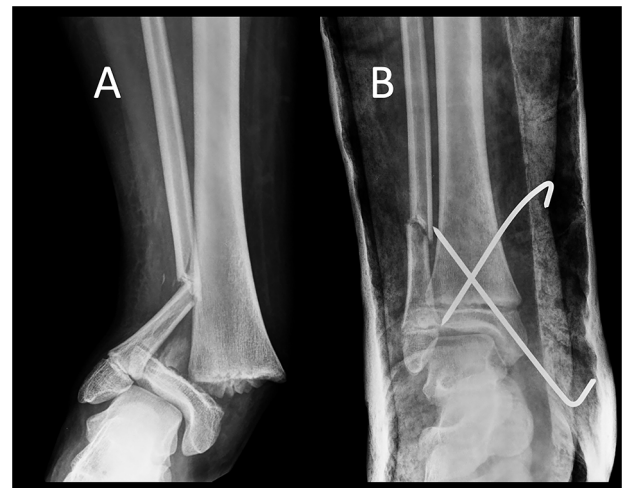
Repeated attempts at closed reduction of a physal injury can cause damage, so the procedure should not be repeated more than once. Furthermore, if the procedure is performed more than a week after the initial injury the risk of damage to the physis during the reduction manoeuvre is increased,<sup>15</sup> thus certain deformities may be inevitable depending on the degree of displacement and the patient's age. In general, prepubertal children, less than 10 years old, maintain a high remodelling capacity. Thus, less than 15° of angulation is considered tolerable under this age, due to the potential for correction. After this age, there will be less remodelling capacity, recommending alignment close to anatomical as goal of treatment.<sup>1,14</sup> After successful closed reduction the use of a long leg cast is recommended in cases of Salter–Harris I or II with significant prior displacement, because they can facilitate better rotational control.<sup>32,37</sup> In our experience a short leg cast that is well-moulded with respect to soft tissue is usually sufficient. The cast is maintained for 4–6 weeks, and radiographic examination is conducted after one week to assess the maintenance of the reduction. If acceptable alignment is not achieved after the closed reduction procedure, as indicated by varus or valgus deviation of 5° or more, antecurvatum or recurvatum of 10° or more, or displacement at the physis level of > 3 mm and/or a joint gap > 2 mm, surgical treatment should be considered.<sup>29,32</sup> This treatment will vary depending on the type of injury involved.

#### Salter–Harris type I and II injuries

Approximately 15% of all ankle fractures are type I injuries, and they are associated with a risk of physal arrest of < 5%. Isolated lesions of the lateral malleolus without evidence of radiological injury are usually diagnosed as type I injuries, but MRI studies have identified ligament injuries or bone oedema as the real cause of pain in some of these injuries.<sup>39</sup> Type II injuries account for 40% of distal tibial fractures, and they are associated with a risk of physal bar development of 16–25%.<sup>40</sup> In type II injuries the fracture crosses through the physis and the metaphysis, forming a triangular segment called Thurston Holland's fragment (Fig. 20), which is usually located on the lateral edge of the metaphysis.<sup>15</sup> In types I and II, residual displacement of > 3 mm is considered a significant risk factor for physal arrest,<sup>41</sup> therefore reduction is recommended. If closed reduction is achieved, immobilization with a short leg cast is maintained for 4–6 weeks, usually with good results.<sup>15</sup> It must be borne in mind that correct reduction is not directly related to a decrease in the incidence of premature closure of the physis.<sup>42</sup> If closed reduction is not achieved a surgical approach may be necessary, with the aim of removing interposed tissues in the fracture. Fixation is usually performed with smooth



**Fig. 20** Radiography (A) and computed tomography (B, C) of the right ankle of an 11-year-old boy with a Salter–Harris type II fracture, depicting a posterolateral Thurston Holland fragment (dotted blue line on the radiograph).



**Fig. 21** Right ankle of a 13-year-old boy with a displaced Salter–Harris type II fracture (A), and subsequent postoperative control after fixation with two laterally crossed smooth K-wires (B).

K-wires, which are inserted crossing through the metaphysis, physis, and epiphysis, either distally or medially (Fig. 21). This fixation should be achieved via the fewest number of procedures possible, and the most central location possible should be used for the K-wires in the physis, to reduce the risk of physical damage. The K-wires are removed after three weeks, and the limb is protected with an immobilizer for 2–3 weeks thereafter, enabling weight bearing.

#### Salter–Harris type III injuries

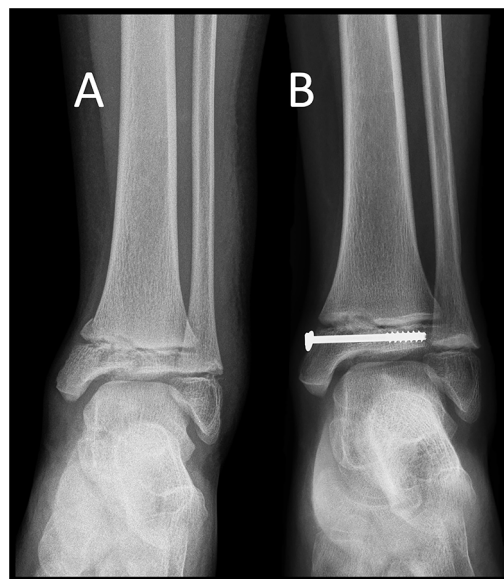
Approximately 25% of all ankle fractures are type III injuries.<sup>40</sup> The most common type III injuries are medial malleolus fractures and juvenile Tillaux fractures.

*Medial malleolus fractures*

Medial malleolus fractures usually present as Salter-Harris type III or IV injuries. If there is  $\geq 1$  mm of displacement surgical fixation is recommended, given associations between these types of fractures and nonunion and physal bar formation.<sup>32,43</sup> We recommend the use of a direct 'J' incision on the medial side in order to adequately visualize the medial corner of the mortise and assess anatomical consistency (Fig. 22). A combination of metaphyseal and epiphyseal screws achieves adequate stability,<sup>44</sup> while avoiding crossing the physis.

*Juvenile Tillaux*

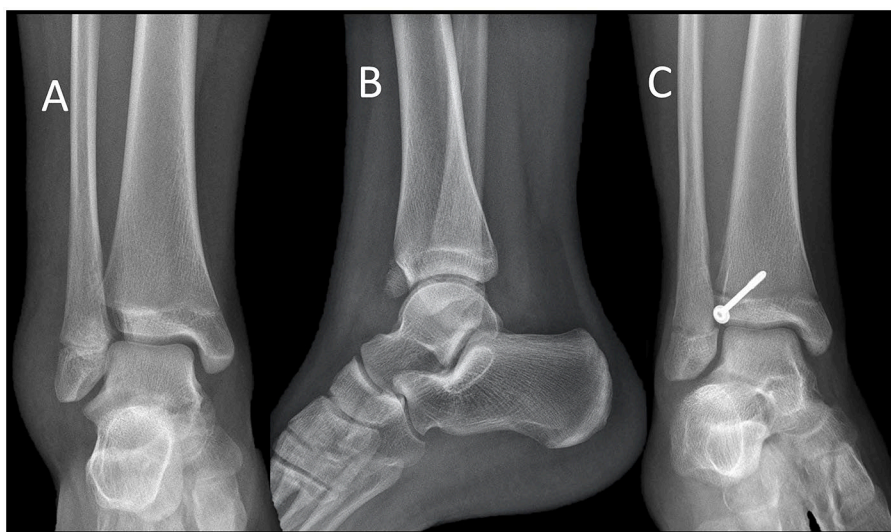
Juvenile Tillaux fractures can be treated conservatively when there is joint incongruity of  $< 2$  mm, using a short leg cast without weight bearing for a period of 3–4 weeks followed by two crutches and protected loading for two weeks.<sup>45</sup> If there is greater displacement, reduction and stabilization are required. Reduction is usually achieved in a closed manner and stabilization is achieved via a 3.5–4.0-mm percutaneous screw, which can cross the physis (Fig. 23). If adequate reduction is not achieved in a closed manner, a minimal approach should be utilized, avoiding injury to the anterior tibiofibular ligament and extensive dissection of the anterior ankle capsule. The decision to perform this treatment should be made early, because the consolidation process is advanced after 7–10 days.<sup>15</sup> When performing fixation with transepiphyseal screws the surgeon should consider their removal after the fracture has consolidated, because it has been shown that the maximum contact pressure increases substantially with use.<sup>46</sup>



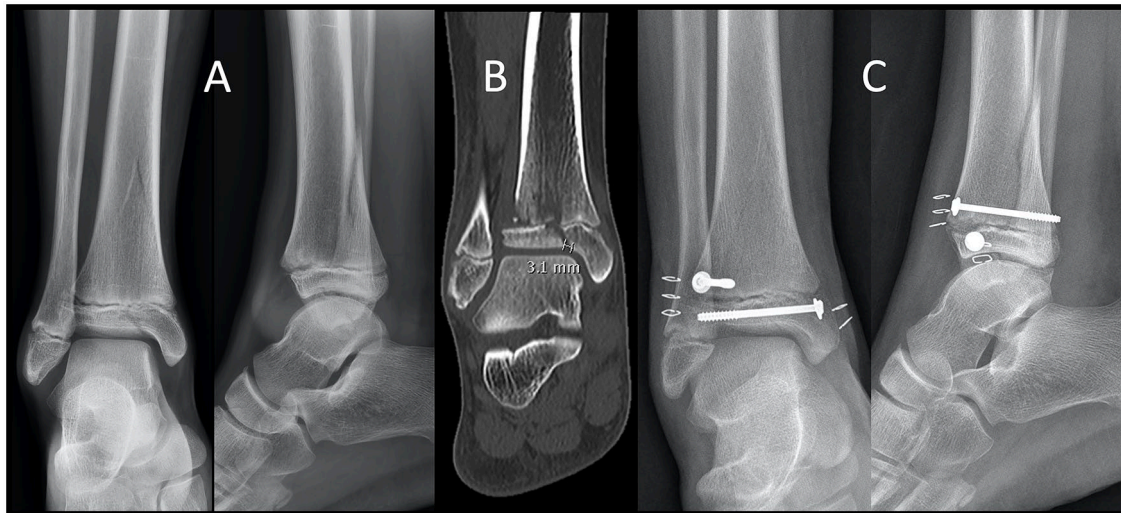
**Fig. 22** Left ankle of a 12-year-old boy with a medial malleolus Salter–Harris type IV fracture (A), and postoperative control after performing open reduction internal fixation with a cannulated screw, without compromising the physis (B).

*Salter-Harris type IV injuries*

Approximately 25% of ankle fractures are Salter–Harris type IV injuries.<sup>40</sup> In the absence of displacement such injuries can be treated conservatively, but they usually do entail a degree of displacement. The presence of step or joint displacement of  $> 2$  mm necessitates surgery to minimize residual joint incongruity and physal bar formation. The types of approach and stabilization utilized depend on the patient's age, the area affected, and the fracture pattern.



**Fig. 23** Right ankle of a 14-year-old girl with a juvenile Tillaux fracture with anterior displacement (A, B). Surgical management was performed using open reduction internal fixation with a transphyseal cannulated screw (C).



**Fig. 24** Anteroposterior view of the right ankle of a 13-year-old boy with a triplanar fracture with a Gothic arch and joint involvement (A). Computed tomography depicted an articular gap  $> 2$  mm (B). Surgery was performed using closed reduction and percutaneous fixation with cannulated screws (C).

#### *Salter–Harris type V injuries*

Salter–Harris type V injuries are rare and result from a compression force through the physis. They are associated with difficult diagnosis via initial radiography, and an associated possibility of physeal arrest is the main concern. If the presence of a physeal bar is recognized early after the injury, resection of the bar may prevent future deformity. These fractures are generally diagnosed months or years after the injury, however, by which time angular deformities and/or discrepancies in the lengths of extremities requiring treatment are already present.

#### *Triplanar fractures*

Triplanar fractures require careful assessment, with the main objective of evaluating the anatomy of the articular surface. For this we recommend CT prior to decision making and surgical intervention. Conservative treatment is indicated if there is no displacement, the joint gap is  $< 2$  mm, or the involvement is extra-articular.<sup>47</sup> In cases requiring surgery the therapeutic goal is reduction and stabilization of steps or displacements at the level of the articular surface of  $> 2$  mm (Fig. 24). If closed reduction is possible, stabilization is performed with percutaneous screws. To achieve adequate joint congruency, anterolateral fragment reduction must be conducted first, followed by posteromedial reduction. In cases requiring open reduction, triplanar fractures involving medial displacement are approached anteromedially, whereas those involving lateral displacement are approached anterolaterally.<sup>26</sup>

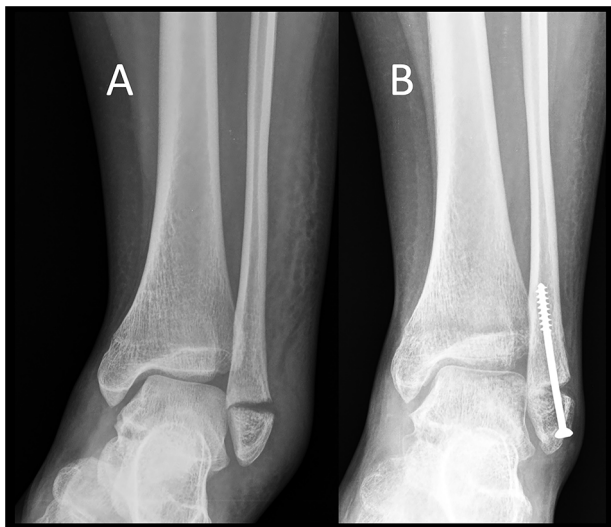
#### *Distal fibula fractures*

Most distal fibula fractures are Salter–Harris type I or II, and most occur in children aged 10–14 years, in isolation

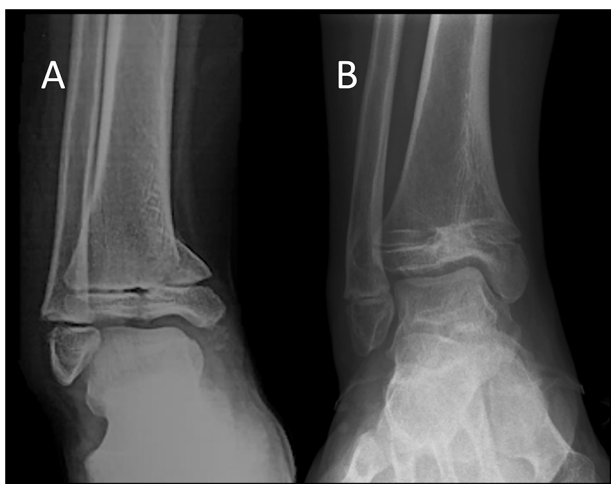
or with minimal displacement. Occasionally they are associated with partial or total rupture of the deltoid ligament without associated tibial fracture, so it is necessary to bear in mind that these types of injuries may require surgery because they can be associated with greater joint instability.<sup>48,49</sup> Distal fibula fractures associated with displaced Salter–Harris type III or IV fractures of the distal tibia usually involve higher displacement.<sup>45,48</sup> In contrast to fractures of the distal tibial physis, fractures of the distal fibular physis evidently entail low risks of shortening, angular deformity, and joint incongruity secondary to a physeal injury.<sup>50</sup> Isolated non-displaced fractures of the fibula can be treated with a short leg cast that enables partial loading, as tolerated, for 3–4 weeks.<sup>3,45,48</sup> In the event of displacement, closed reduction can be performed and stabilization can be achieved via a screw (Fig. 25) or K-wire positioned vertically percutaneously.<sup>45</sup>

## Complications

The possibility of premature closure of the physis is a relevant problem in paediatric ankle fractures and generally occurs in Salter–Harris type III or IV injuries.<sup>45</sup> Complete physeal arrest can result in a difference between the lengths of the lower extremities, and partial injuries of the physis can result in angular deformities. Usually the physes of the tibia and the fibula are not affected in the same way, resulting in asymmetric growth of the ankle mortise.<sup>45</sup> It has been reported that the Park–Harris lines are reliable predictors of a growth abnormality. Park–Harris lines that are parallel to the physis indicate normal growth, whereas divergence from this course indicates possible alteration in growth.<sup>1</sup> CT and MRI can facilitate



**Fig. 25** Left ankle of a 14-year-old girl with a Salter–Harris type I fracture of the distal fibula (A). Closed reduction and stabilization with a percutaneous screw were performed (B).



**Fig. 26** Right ankle of a nine-year-old girl with medial malleolus Salter–Harris type IV fracture (A). Non-operative treatment with cast immobilization was performed. After 14 months, varus deformity with physeal bar formation is observed (B).

physeal bar evaluation. Physeal bar treatment depends on the timing of the diagnosis, the degree of physeal involvement, and the presence of deformity.<sup>51</sup>

Malunion is a potential complication of ankle fractures. It is rare in Salter–Harris type I injuries due to the high potential for remodelling. Conversely, up to 11% of Salter–Harris type II injuries can involve poor angular union.<sup>48</sup> Delayed consolidation and nonunion are relatively uncommon in paediatric patients,<sup>3</sup> but they can be a significant problem in Salter–Harris type III and IV fractures of the medial malleolus (Fig. 26). To reduce the

risk in these types of fractures, stabilization with internal fixation is recommended.

## Conclusions

Paediatric ankle fractures are common in clinical practice. Specific fracture patterns are associated with different patient age ranges. The presence of physeal injuries is common, and they can compromise joint surfaces. Angular deformities and alterations of the articular surface can result in substantial functional problems, so their management should be aimed at avoiding these situations. CT is informative for the assessment of injuries involving joint compromise, and it provides information about the joint gap and the characteristics of the different fragments, particularly with regard to triplanar fractures, facilitating good preoperative planning.

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