Evidence-Based Management of Ankle Fractures in Children

22

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Abstract

Ankle fractures in children are common and pose unique diagnostic and therapeutic challenges. In this chapter we investigated and summarised the strength of evidence behind methods of assessing and treating these fractures. Lateral and mortise views are indicated when Ottawa ankles rules are positive. AP view does not add more information (grade B). Computed tomography is useful adjunct for assessment and management planning in selected cases (grade B). Undisplaced ankle fractures can be effectively managed with cast immobilisation and close radiographic follow-up evaluation (grade B). Reduction (closed or open) and internal fixation should be considered when there is a displacement (grade B/C); however the cut off for what is considered displaced has not been universally agreed on. Most published studies used 2 mm displacement as a cut off for operative treatment; hence there is a lack of evidence on the outcomes of non operative treatment when the displacement is more than 2–3 mm.

Keywords

Ankle fractures • Transitional fractures • Tillaux fractures • Triplane fractures • McFarland fractures • Salter-Harris classification

Introduction

The ankle joint is a modified hinge joint between the tibial plafond, medial and lateral malleoli proximally and the talus distally. The ankle joint is stabilised by several ligaments which are essential for normal function. These ligaments include the anterior talofibular (ATFL), calcaneofibular (CFL) and posterior talofibular ligaments (PTFL) laterally, and the deltoid ligament medially. The lower ends of the tibia and fibula articulate together forming the inferior tibiofibular joint (ITFJ) which is stabilised by the anterior tibiofibular (ATiFL), interosseous ligament and posterior tibiofibular (PTiFL) ligaments [1].

The distal tibial epiphysis starts ossifying between 6 and 24 months of age and ossification extends into the medial malleolus around 7 years. In 20 % of cases there is a separate ossification centre in the medial malleolus. This should not be confused with a fracture. The distal tibial physis closes over an 18-month period starting around age 14 years in girls and 16 years in boys. The central part of the physis closes first, followed by the medial side and lastly the lateral side (Fig. 22.1).

The distal fibula epiphysis starts ossifying during the second year of life and closes 12–24 months later than the distal tibial physis. The distal tibial physis grows 4 mm a year and account for 40 % of the leg longitudinal growth.

Stability is a very important concept in the management of ankle fractures. Ligaments play a major role in ankle

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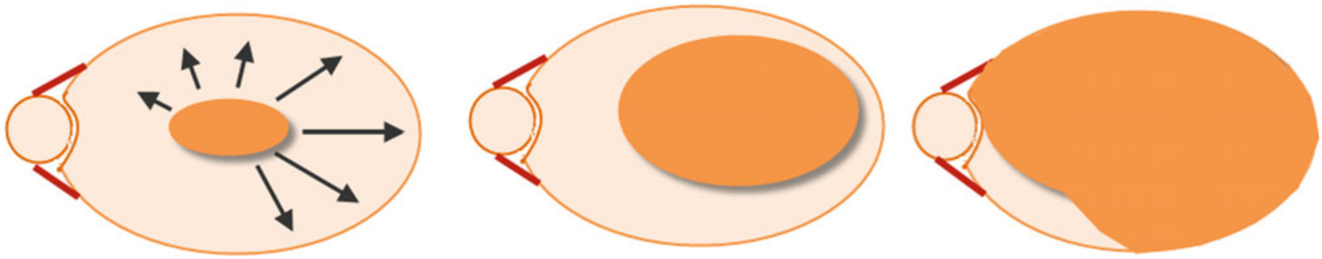


Fig. 22.1 Progression of physeal closure of the distal tibia

Table 22.1 AO ankle fracture classification

Type A	Type B	Type C
A1 Infrasyndesmotic lesion, isolated 1. Rupture of the lateral collateral ligament 2. Avulsion of the tip of the lateral malleolus 3. Transverse fracture of the lateral malleolus	B1 Transsyndesmotic fibular fracture, isolated 1. Simple 2 Simple, with rupture of the anterior syndesmosis 3 Multifragmentary	C1 Suprasyndesmotic lesion, diaphyseal fracture of the fibula, simple 1. With rupture of the medial collateral ligament 2. With fracture of the medial malleolus 3. With fracture of the medial malleolus and a Volkmann (= Dupuytren)
A2 Infrasyndesmotic lesion, with fracture of the medial malleolus 1. Rupture of the lateral collateral ligament 2. Avulsion of the tip of the lateral malleolus 3. Transverse fracture of the lateral malleolus	B2 Transsyndesmotic fibular fracture, with medial lesion 1. Simple with rupture of the medial collateral ligament and rupture of the anterior syndesmosis 2. Simple with fracture of the medial malleolus and with rupture of the anterior syndesmosis 3. Multifragmentary	C2 Suprasyndesmotic lesion, diaphyseal fracture of the fibula, multifragmentary 1. With rupture of the medial collateral ligament 2. With fracture of the medial malleolus 3. With the fracture of the medial malleolus and a Volkmann (= Dupuytren)
A3 Infrasyndesmotic lesion, with postero-medial fracture 1. Rupture of the lateral collateral ligament 2. Avulsion of the tip of the lateral malleolus 3. Transverse fracture of the lateral malleolus	B3 Transsyndesmotic fibular fracture, with medial lesion and a Volkmann (fracture of the postero-lateral rim) 1. Fibula simple, with rupture of the medial collateral ligament 2. Fibula simple, with fracture of the medial malleolus 3. Fibula multifragmentary, with fracture of the medial malleolus	C3 Suprasyndesmotic lesion, proximal fibular lesion 1. Without shortening, without Volkmann 2. With shortening, without Volkmann 3. Medial lesion and a Volkmann

fracture stability. In practice most surgeons base their decisions on clinical assessment and plain x-rays to assess ankle fracture stability. Although this may be adequate in most cases where the features of instability are obvious, this is not the case in all fractures leading to some patients undergoing unnecessary surgery. In children, this is even more complicated due to the presence of the physis which poses diagnostic and therapeutic challenges to the treating surgeons.

Stress tests, CT scan and MRI scan have been used to aid decision making.

Several classifications have been proposed to help understand the nature of ankle fractures, inform treatment choices and predict future outcomes. Most of these have been based on morphological description and their predictive values for instability and better treatment choice have been questioned [2, 3]. However, to understand the published evidence better, basic knowledge of these classifications is valuable.

In adult practice, there are two common classifications in use: Weber and Lauge-Hanson classification.

Weber classified ankle fractures according to the relation of the fibular fracture to the syndesmosis into: type A (below the syndesmosis), type B (at the level the syndesmosis) and type C (above the syndesmosis). Weber classification was subsequently adopted and incorporated in the AO ankle classification which was expanded into two sub-layers as shown in Table 22.1.

Lauge-Hansen [4] classified ankle fractures according to the position of the foot at the time of impact (supinated or pronated) and the direction of the force applied to the ankle (adduction, abduction or external rotation). A pronated foot will result in tight deltoid ligament and lax lateral ligamentous complex and vice versa for a supinated foot. Lauge-Hansen indicated that these two elements (the position of the foot and the direction of the force) determine the order in which ankle stabilising structures fail, and that these structures fail in a predictable order (Table 22.2). Several biomechanical studies failed to reproduce the work and classification of Lauge-Hansen [5, 6]). Moreover, findings from MRI

Table 22.2 Lauge-Hansen classification

Lauge-Hansen class	Sequence of structures failure with increasing force caused by an injury
Supination – external rotation (SER)(foot is supinated and the force is external rotation)	Stage I: ATiFL rupture or avulsion fracture of tibia or fibula
	Stage II: short oblique fibula fracture (anteroinferior to posterosuperior)
	Stage III: PTiFL rupture or avulsion of posterior malleolus
	Stage IV: Medial malleolus transverse fracture or disruption of deltoid ligament
Supination – adduction (SA)	Stage I: Talofibular sprain or distal fibular avulsion
	Stage II: Vertical medial malleolus and impaction of anteromedial distal tibia
Pronation – abduction (PA)	Stage I: Medial malleolus transverse fracture or disruption of deltoid ligament
	Stage II: ATiFL rupture or avulsion
	Stage III: Transverse comminuted fracture of the fibula above the level of the syndesmosis
Pronation – external rotation (PER)	Stage I: Medial malleolus transverse fracture or disruption of deltoid ligament
	Stage II: ATiFL disruption
	Stage III: Lateral short oblique or spiral fracture of fibula (anterosuperior to posteroinferior) above the level of the joint
	Stage IV: Posterior tibiofibular ligament rupture or avulsion of posterior malleolus

studies of displaced ankle fracture did not have the patterns of ligament and bony injury predicted by their apparent Lauge-Hansen type [1, 2, 7].

Salter and Harris introduced a classification system which carries their name based on the relationship of fracture lines to the growth plate [8, 9]. The classification is relatively simple and easily remembered and has been relatively successful in predicting future growth disturbance although the latter has been contested [10]. (Fig. 22.2)

Dias and Tachdjian [11] modified the Lauge-Hansen classification to include the Salter-Harris classification so that it can applied to children ankle fractures. Subsequently four other types of fractures were added, namely the Tillaux, triplane, axial compression, and miscellaneous physeal fractures [12].

Tillaux fracture and triplane fractures have been added to the classification. The juvenile Tillaux fractures (to differentiate it from adult similar avulsion fracture) are SH-III fractures involving the anterolateral aspect of the distal tibia plafond which is not fused to the metaphysis yet (Fig. 22.3). These fractures are caused by external rotation forces and can be reduced by internally rotating the foot [13].

The triplane fracture was described by Lynn in 1972 [14]. As the name implies these fractures occur in three different planes: coronal, transverse, and sagittal. On the AP radiographs the fracture appears as a SH-III (like Tillaux fracture) whilst on the lateral view it appears as a SH-II (also called two-part triplane fracture) or SH-IV (also called three-part triplane fracture). Four-part triplane was also described in the literatures [15, 16] (*see* Figs. 46.1 and 46.2 in Chap. 46).

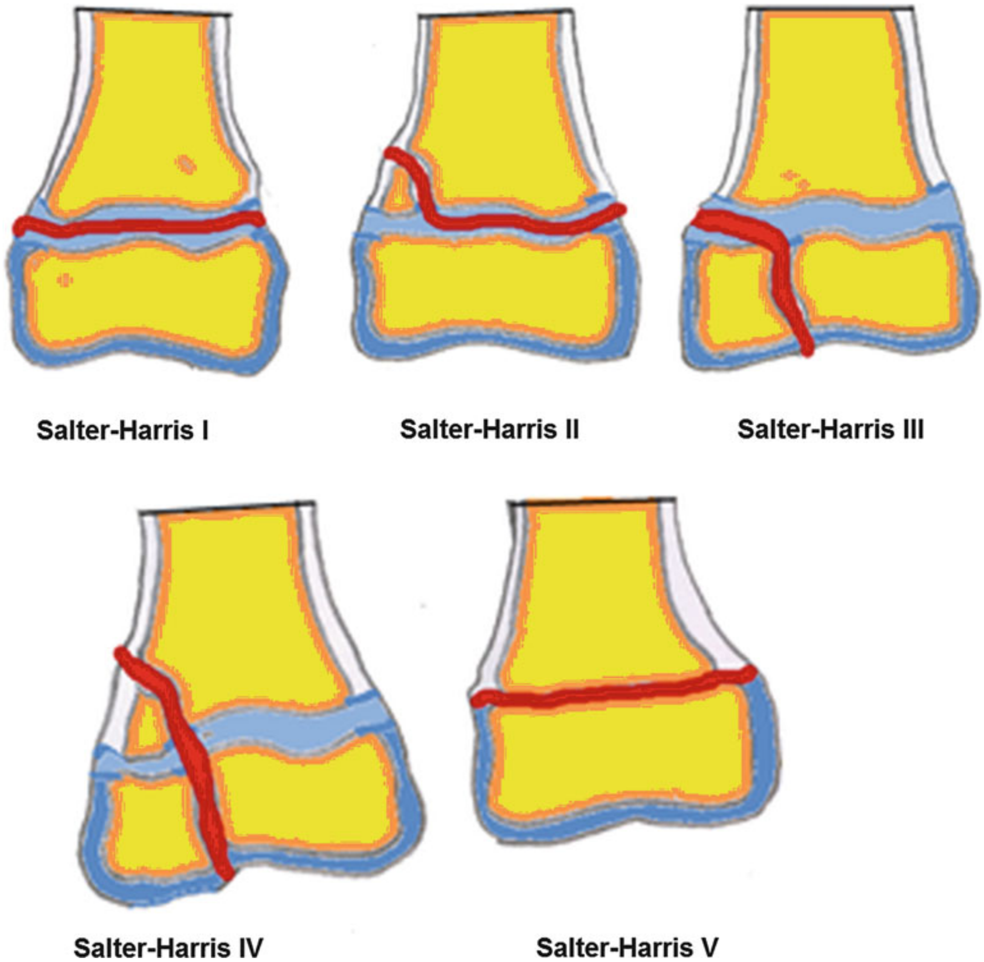
The prognostic value of these classifications has been debated. Leary [10] retrospectively reviewed 124 children after physeal fractures of the distal end of the tibia. They defined premature physeal closure (PPC) as radiographic evidence of physeal closure as compared to the uninjured side in this patient population. Fifteen fractures (12.1 %) were complicated by PPC, 67 % of the PPC observed occurred in SH-II fractures, followed by 13 % in SH-III, 13 % in SH-IV, and 7 % in triplane fractures. They did not observe any physeal arrest in the SH-I or Tillaux fractures. They were able to demonstrate statistically significant correlations between mechanism of injury and PPC and between the amount of initial fracture displacement and the rate of PPC. For each millimetre of initial displacement, there was a relative risk of 1.15 ($P < 0.01$).

In another study of 49 children with physeal fractures of the distal tibia or fibula or both, the Salter-Harris classification system could not significantly predict the growth pattern [17] (Fig. 22.2).

Spiegel et al. [18] followed 184 distal tibia and/or fibula, fractures for an average of 28 months after injury using the Salter-Harris classification. They differentiated three groups according to their risk for shortening of the leg, angular deformity of the bone, or incongruity of the joint. The low-risk group consisted of 89 patients, 6.7 % of whom had complications; this group included all type I and type II fibula fractures, all type I tibia fractures, type III and type IV tibia fractures with less than 2 mm of displacement, and epiphyseal avulsion injuries. The high-risk group consisted of 28 patients, 32 % of whom had complications; this group included type III and type IV tibia fractures with 2 mm or more of displacement, juvenile Tillaux fractures (Fig. 22.3), triplane fractures, and comminuted tibial epiphyseal fractures (type V). The unpredictable group was made up of 66 patients, 16.7 % of whom had complications; only type II tibia fractures were included. The incidence and types of complications were correlated with the type of fracture (Salter-Harris classification), the severity of displacement or comminution, and the adequacy of reduction.

de Sanctis et al. [19]) reviewed 158 ankle fractures; 132 were treated conservatively and 26 patients underwent surgical

Fig. 22.2 Salter-Harris classification of physeal injury



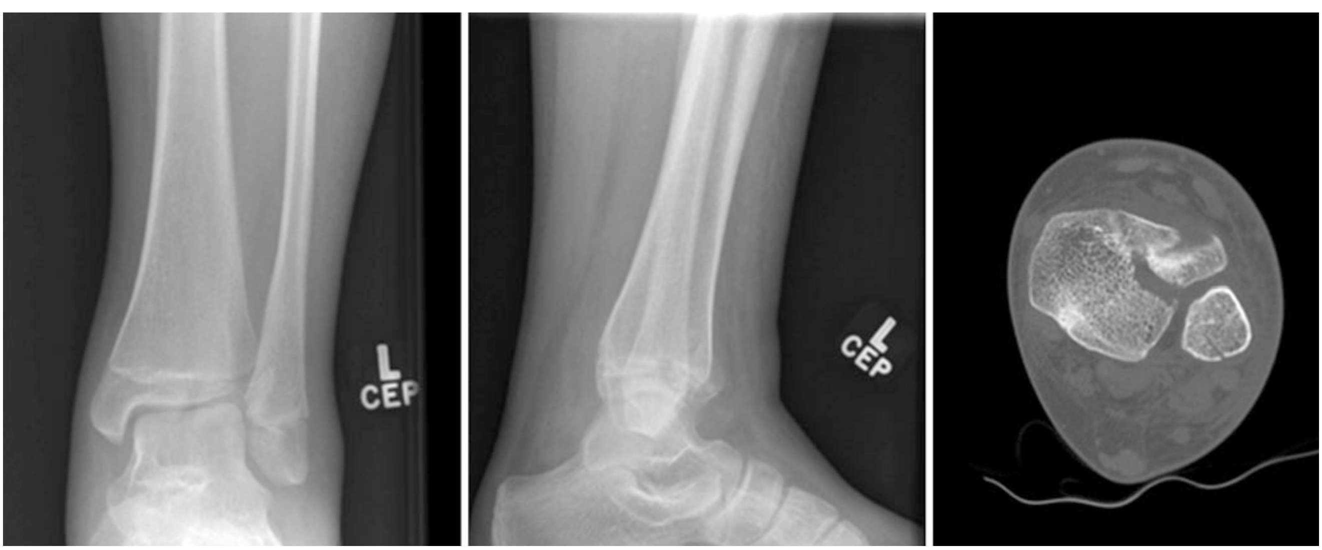


Fig. 22.3 Tillaux fracture

treatment. Fibular fractures of the malleolus without epiphyseal separation or dislocation (68 patients) were excluded. Of the 158 patients, 113 (70 %) were available for an average 6-year follow-up. They compared the degree of epiphyseal separation or dislocation, the Carothers-Crenshaw classification (a classification based on the mechanism of trauma) with the Salter-Harris classification (which is based on anatomical-radiographic criteria). They reported that fractures more likely to result in permanent damage to the physis are those caused by a traumatic adduction-supination mechanism that can produce SH-III, IV, and V fractures of the distal part of the tibia; they also reported that the combination of compression and

Table 22.3 The outcomes after various types of Salter-Harris fractures

Type of fractures	Good outcome	Poor outcome	Total
SH-I	180	1	181
SH-II	107	6	113
SH-III	58	8	66
SH-IV	15	1	16
Total	360	16	376

adduction may cause a SH- V injury with type III and IV fractures. However, type V lesions are often diagnosed late. In 11 of their 12 poor results, 6 were caused by adduction-supination injuries and 5 were compressive injuries.

In a large retrospective study of 376 children with distal tibial physeal injury, Schurz et al. [20] reported the outcomes after various types of Salter-Harris fractures (Table 22.3).

Vahvanen and Aalto [21] studied 310 children treated for ankle fractures. They were classified according to the classifications of Ashhurst-Bromer-Weber, Lauge-Hansen, and Salter-Harris. They found that grouping of the fractures according to Lauge-Hansen and Ashurst-Bromer-Weber classifications suited to adults was largely unsuccessful. Epiphyseal fractures were easily classified according to Salter-Harris. They proposed that ankle fractures in children can be roughly divided into avulsion and epiphyseal fractures. Adequately reduced avulsion fractures can be expected to heal well; epiphyseal fractures, however, may cause late complications.

What Is the Evidence Behind Ankle Fractures Investigation?

Ottawa Rule

Ankle injury is common and radiological tests are not always indicated. The Ottawa ankle rules [22, 23] have been shown to be accurate in predicting the need for radiography in the acute trauma situation in adults. They can be used by medical and nursing staff in a variety of settings, and can reduce unnecessary radiography ([24, 25]; Allerston and Justham [26–28]). Several studies showed their value in detecting ankle fractures in children [29–36]. In a review by Crocco [37] of 671 fractures, the sensitivities of the Ottawa ankle rules ranged from 83 % to 100 % and specificities from 7.9 % to 50 %. X-ray reduction rates ranged from 5 % to 44 % (pooled reduction rate 25 %, 95 % CI: 23–26 %).

Plain Radiograph

The standard plain radiographic views of the injured ankle are antero-posterior (AP), the mortise and lateral views. The mortise view is a modified AP with the ankle internally rotated so that the malleoli are in the same horizontal plane and the joint space is seen evenly on both sides of the ankle. This requires 10°–20° of internal rotation. The need for three views has been questioned. Brage [38] found that ankle fractures could be classified with two radiographic views as reliably as with three views. Four different observers independently evaluated 99 sets of ankle radiographs. The examiners classified the ankle fractures by using both the Lauge-Hansen and Weber systems. The interobserver and intraobserver variations were analyzed by kappa statistics. The study demonstrated that ankle fractures can be classified with two views, lateral or mortise, with a reliability as good as that achieved with three views. The best agreement was achieved with lateral and mortise views. Adding a true AP view did not add useful information.

In a study by Vangsness [39], 123 sets of emergency room ankle x-rays (AP, lateral and mortise) were retrospectively reviewed to determine whether all three views were necessary to diagnose the presence of an ankle fracture. Four physicians (two orthopaedic surgeons, one musculoskeletal radiologist, and one emergency room physician) reviewed all randomly ordered sets of films twice – once with all three views and once with only the lateral and mortise views. The overall accuracy of two views was within the 95 % expected threshold of accuracy using three views. The lateral and mortise views alone appear sufficient for ankle fracture diagnosis, and imply a substantial decrease in radiation and cost savings.

The Role of Medial Clear Space

The presence of an ankle fracture on plain x-ray is not an indication for surgery and stable fractures may do not even require cast protection. Signs of instability are more important than the presence of a fracture as such. Displacement is often used to indicate instability (Fig. 22.4). Murphy et al. [40] measured medial and superior clear space in 73 patients without ankle injuries. Seventeen percent of male x-rays and 1 % of female x-rays had a medial clear space >4 mm, while 2 % of males and no females had a medial clear space >5 mm. Thirteen percent of radiographs had a medial clear space greater than superior clear space. Measurements were symmetrical, so the authors suggest the use of contralateral comparison radiographs to evaluate apparent medial widening. Koval et al. [41] suggested that a 4 mm medial clear space indicates an intact medial deltoid ligament and a stable ankle.

Schuberth [42] showed that medial clear space was a poor predictor of arthroscopically-diagnosed deltoid ligament tears. They found the 88.5 % false positive rate for deltoid ligament rupture when medial clear space > or = 3 mm (P = .54, Fisher's exact test) and 53.6 % when medial clear space > or = 4 mm (P = .007).

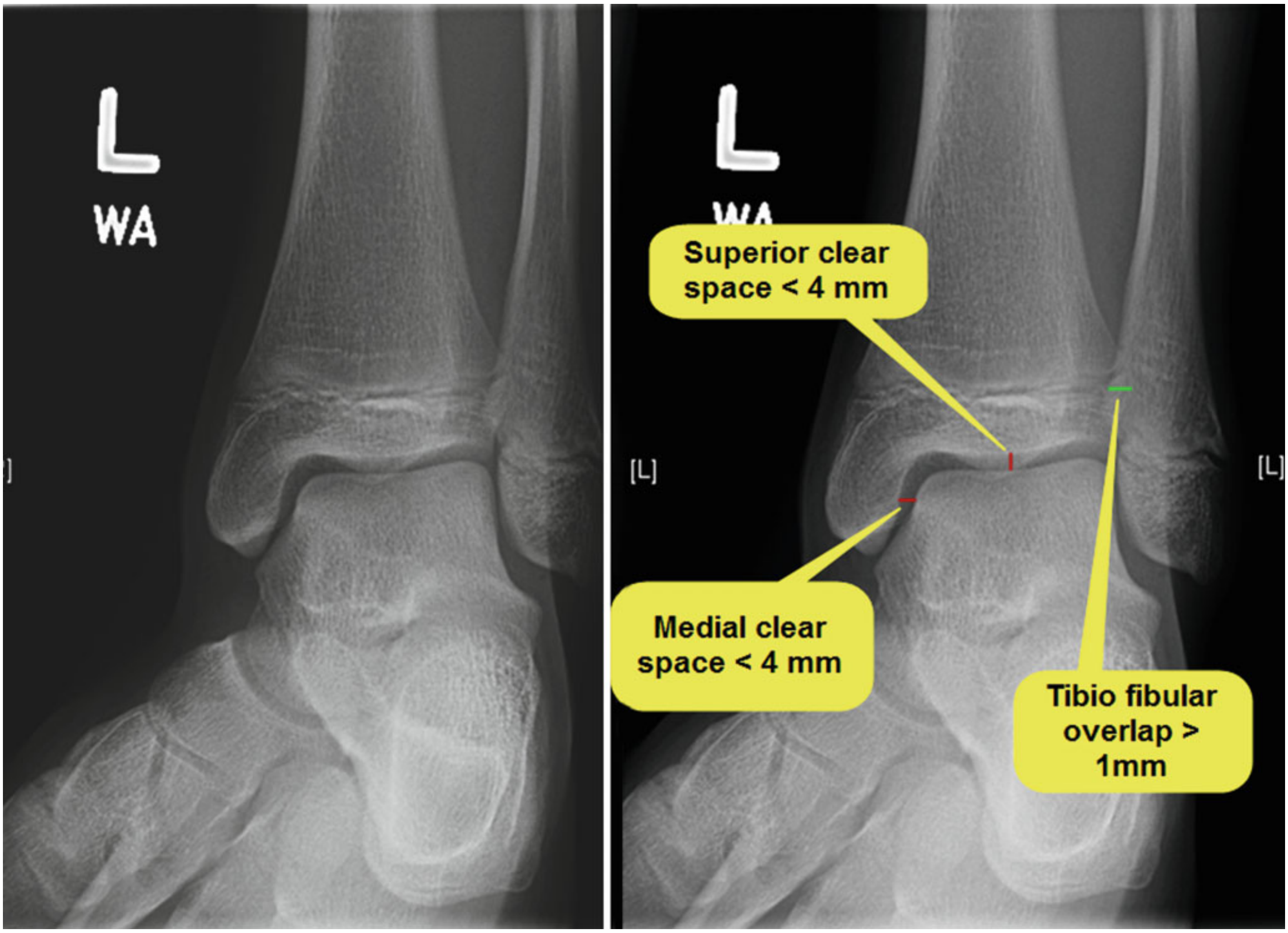


Fig. 22.4 Mortise view showing medial and superior clear space

Several studies [41, 43, 44] have suggested that external rotation stress (manual or gravitational) x-ray can differentiate stable from unstable undisplaced fractures when plain x-rays are inconclusive. These studies assumed ankle instability when the clear medial space increased more than 4 mm with stress. However, this has been contested. Koval [41] investigated the significance of positive stress radiographs (medial clear space >5 mm on stress testing) in 21 patients who. All had MRI scan; 19 patients had evidence of partially torn deep deltoid ligament and their ankles were not stabilised whereas two had a complete rupture of the deep deltoid ligament and underwent stabilisation. All fractures united without evidence of residual medial clear space widening or posttraumatic joint space narrowing.

Several other studies concluded that stress radiographs greatly over-estimate instability and that most undisplaced ankle fractures can be treated non-surgically [45–47]. Most of these studies include only a few children and adolescents so their findings may not be applicable to paediatric practice.

The Role of CT Scan

CT can be useful in assessing more complex ankle fractures for accurate diagnosis, preoperative planning, and assessment of reduction of intra-articular fractures. However, clear indications are still lacking and reasoning remains subjective. A recent study of 64 distal tibial fractures with intra-articular involvement demonstrated the importance of CT scan in assessment [48]. All patients had plain radiographs and CT scans. Findings based on radiographs and CT scan are summarised in Table 22.4. Authors concluded that CT scan led to changes in fracture classification and treatment decision.

Table 22.4 The difference in classification and decisions of surgical treatment when CT scan was used in 64 patients with ankle fracture

	Palin radiograph	Adding CT Scan
SH-III fracture	31	20
SH-IV fracture	8	12
Tillaux fracture	9	9
Triplane fracture	16	23
Decision for operative treatment	18	42
Decision for non operative	46	22

In a similar study of 25 triplane fractures by Eismann [49], there was poor inter-rater reliability (a kappa of 0.17) and intra-rater reliability (a kappa of 0.31) with radiographs alone but moderate inter-rater reliability (a kappa of 0.41) and intra-rater reliability (a kappa of 0.54) with the addition of computed tomography. More interestingly, the decision from non-operative to operative treatments was changed in 27 % and either the orientation or number of screws was changed in 41 % of the cases when raters reviewed CT scans.

Black et al. [50] performed a retrospective analysis on 100 consecutive patients treated for ankle fractures having both preoperative radiographs and CT scans. They found operative strategy was changed in 24 % of cases after CT review. Several authors suggested that CT scan should be routinely performed in clinical practice [51, 52].

The Role of Magnetic Resonance Imaging (MRI)

MRI provides fine detail of bones and soft-tissue structures and does not involve radiation. MRI scans have been used to diagnose occult fractures and, in cases of incomplete ossification of malleoli, to establish displacement [41, 53].

Lohman et al. [53] studied 60 children with acute ankle injuries with both conventional radiography and MR. Plain radiography produced 5 of 28 (18 %) false negative and 12 of 92 (13 %) false positive fracture diagnoses compared to MRI. However they found no complex ankle fracture was missed and the MRI did not change the treatment plan in any case.

Petit et al. [54] compared radiographs with MRIs for 29 children with physeal ankle injuries and found only 1 of 29 fractures (3 %) was misclassified by plain film radiography.

Contrary to these two studies, Carey et al. [55] reported on 14 patients with suspected physeal injuries and indicated that that the MRI scans led to a change in the Salter-Harris classification for two of the nine patients with fractures seen on radiographs, they identified two occult fractures, and changed the management in five patients.

What Is the Best Treatment for Non-displaced Ankle Fractures in Children?

There is a consensus on non operative treatment of stable and undisplaced ankle fractures. Many centres use a below knee full cast to treat undisplaced stable fractures although this may not be necessary in every case. In a randomised controlled study (level I) of 40 patients with Lauge-Hansen supination-eversion, stage II ankle fractures, the use of the air stirrup led to a significant improvement in early patient comfort, post-fracture swelling, range of ankle motion at union, and time to full rehabilitation in comparison to a below knee walking cast [56].Similar findings were found in 66 patients who were treated with Aircast Stirrup ankle braces or Don Joy R.O.M.-Walker braces [57]. Subjective satisfaction with comfort and ease of use was significantly higher with Aircast Stirrup while pain relief and an inflammatory score were significantly better in the R.O.M.-Walker group after 4 weeks. There was in difference in outcomes after 3 months.

The above may be not true for unstable fractures where there is a potential for fracture displacement. Defining stability when there is no displacement remains controversial and the cut-off between stable and non-stable fractures has not yet been fully defined [1]. Several clinical and radiological signs have been proposed to signify instability including medial tenderness, bruising or swelling, fibular fracture above the syndesmosis and high energy fractures but none is confirmatory. Stress views have been used to diagnose instability; however several studies showed that even in the presence of a positive stress views conservative treatment in a brace or cast usually produced satisfactory union in an undisplaced position [41, 44, 46, 58].

What Is the Treatment for Displaced Paediatric Ankle Fractures?

The decision for operative intervention is obvious when displacement is substantial. The aim is for gentle reduction to as anatomical position as possible is desirable and often achievable. However, when displacement is minor, the decision for intervention can be tricky. Correct identification of a child ankle fracture according to Dias-Tachjidian classification aids (Table 22.5) its close reduction. We describe below the current approach to treat displaced fractures based on Salter-Harris classification.

Table 22.5 Dias-Tachdjian classification of children ankle fracture

Dias and Tachdjian	Sequence of structures failure with increasing force caused by an injury
Supination – external rotation (SER) (foot is supinated and the force is external rotation)	Stage I: SH-II fracture of the distal tibial epiphysis with a posterior metaphyseal-epiphyseal fragment displaced posteriorly. The distal tibial fracture begins on the lateral distal aspect and spirals medially and proximally. The fibula remains intact. This fracture is similar to a supination–plantar flexion injury, especially when seen on the lateral radiograph; the distinction is that the distal tibial fracture line begins on the distal lateral aspect and spirals medially when viewed on the AP projection
	Stage II: spiral fracture of the fibula. The fracture begins medially and extends superiorly and posteriorly
Supination – inversion injury (foot is supinated and the force is adduction or inversion)	Stage I: traction by the lateral ligaments produces a SH-I or II fracture of the distal fibular physis. Lateral ligamentous injury can occur but is rare as the physis is usually weaker than the ligament
	Stage II: the talus impacts against the medial malleolus causing SH III or IV injury, occasionally a SH-II and rarely type I of the distal tibia
Pronation–eversion–external rotation fracture	SH-I or II fracture of the distal tibia with a transverse or short oblique fibular fracture located 4–7 cm proximal to the tip of the lateral malleolus When a SH-II fracture occurs, the metaphyseal fragment is located laterally or posterolaterally and the distal tibial fragment is displaced laterally and posteriorly
Supination–plantar flexion injury	SH-II physeal injury of the distal tibial physis with posterior displacement of the epiphyseal-metaphyseal fragment and no fracture of the fibula. The metaphyseal fragment of the tibia is posterior and best seen on a lateral radiograph

Table 22.6 Growth disturbance in distal tibial ankle fracture

Types of fractures	Rate of growth disturbance (%)
SH-III and IV (medial malleolar type) fractures	38
SH-I and II fractures	36
Triplane fracture	21
Tillaux fractures	0

Salter-Harris Type I and II Tibial

These two types of ankle fractures usually behave in the same way. SH-I is relatively rare (15 %) whereas SH-II is common (38 %) of all distal tibial fractures in children [18]. Treatment consists of gentle closed reduction by reversing the original mechanism of injury, followed by an above knee cast immobilisation. Follow-up is recommended in the first week to ensure no further displacement.

In a retrospective study of 92 distal tibial physeal fracture by Barmada [59], 25 fractures (27.2 %) were complicated by growth disturbance. These are summarised in Table 22.6.

They found that initial displacement, number of reduction attempts, or treatment method did not significantly affect the incidence of growth disturbance. However, the more anatomic reductions resulted in a statistically significant decrease in growth disturbance rates. The rate of growth disturbance was tripled when a residual gap was seen on the radiograph (60 % vs. 17 %).

In another study by Rohmiller et al. [60], around 40 % of 91 distal tibial SH-I or II developed growth disturbance. The mechanism of injury was significant in developing growth arrest: 35 % (17/48) in patients with a supination-external-rotation-type injury (SER) and 54 % (14/26) in patients with pronation-abduction-type injuries (ABD). Initial displacement was significantly greater in patients with ABD (11.7 + 8 mm) injuries than those with SER (4.9 + 3 mm) ($P = 0.001$). Non-operative treatment resulted in growth disturbance in 56 % of cases in comparison to 16 % with operative treatment, this was not statistically significant ($P = 0.16$). They also reported that the most important determinant of growth disturbance is the fracture displacement following reduction. It is of note that both above studies came from the same centre and almost the same time and likely to represent the same cohort of patients.

Salter-Harris Type III and IV Tibial

These fractures types are challenging because of the involvement of the articular surface as well as the physis. They occur in approximately 20 % and 1 % of all distal tibiofibular fractures in children. They encompass a variety of anatomically distinct fractures such as Tillaux fracture (SH-III of the anterolateral tibial plafond), McFarland fracture (SH-III or IV of the medial tibial plafond) and triplane fracture. Treatment of undisplaced fractures consists of protection with a cast and careful follow-up on a weekly basis to ensure maintenance of fracture. Fractures that are displaced more than 2 mm should be reduced by either closed or open reduction followed by screw fixation.

Spiegel [18] reported that 88 % (46/52) of these fractures occurred on the medial side of the tibial plafond. They are also called **McFarland fractures** (Fig 22.5) and they have been associated with a high rate of growth disturbance.

Petratos et al. [61] reported on 20 children with surgically treated McFarland fractures at a mean follow-up of 8.9 years. Seven children (35 %) developed growth disturbance and angular deformity. Initial displacement of more than 6 mm

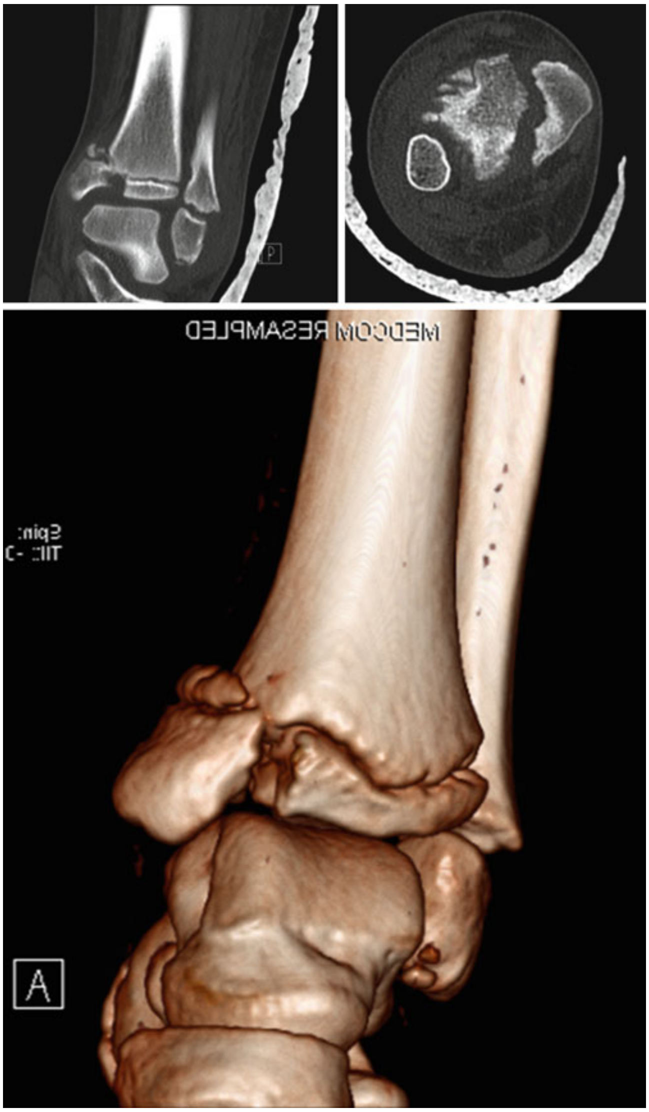


Fig. 22.5 McFarland fracture

(p = 0.004) and operative delay beyond 24 h (p = 0.007) were significant risk factors for growth disturbance.

Kling et al. [62] evaluated 37 children with established growth arrest (drawn from two different cohorts of ankle fractures) and found that 75 % had been treated by closed methods. Most of these were not anatomically reduced.

Cottalorda et al. [63] reviewed 48 patients with McFarland fractures (30 SH-III and 18 SH-IV). All fractures were displaced >1 mm, meeting their operative indications, and were treated with open arthrotomy and fracture reduction under direct visualisation with screw (46) or pin (2) fixation. They reported 45 good and 2 fair results, and only one patient with angular deformity (6° of varus) at a mean follow-up of 3.25 years.

Schurz et al. [20] reported on a large retrospective series of 376 patients. All non-displaced fractures were treated by plaster cast immobilisation (118 children). Displaced fractures, regardless the degree of displacement, were treated by open or closed reduction, with or without internal fixation, to achieve an absolutely anatomical reduction. They showed that 77 displaced physeal fractures of the distal tibia were reconstructed anatomically by open or closed reduction and produced 95 % excellent results. They recommended a perfect anatomical reduction, if necessary by open means, should be achieved to prevent a bone bridge with subsequent epiphysiodesis and post-traumatic deformities due to growth inhibition and/or retardation.

Tillaux fracture was first described by Cooper in 1822 then by Tillaux in 1848 [64–66] and it is the result of avulsion injuries of the lateral epiphyseal plate caused by external rotation of the ankle. The lateral part of physeal plate is usually the last to close. And the timeline for this fracture is during an 18 month period of late growth [67]. The current treatment vogue is non operative treatment when displacement is less than 2 mm and either closed or open reduction and stabilisation when the displacement is more than 2 mm [12]. Excellent outcomes have been widely reported with the above treatments options [68–74]. However there is a lack of long term studies to show similarly good outcome following non operative treatment in Tillaux fracture with displacement of more than 2 mm.

Triplane fractures of the distal tibia are relatively uncommon. They account for 6–8 % of all distal tibial physeal fracture [12, 18, 75]. The treatment options of triplane fractures are not different form that of Tillaux ones. The goal of the treatment is to achieve anatomic reduction of the distal tibial articular surface to prevent potential long-term degenerative changes. When fracture displacement is minimal (<2 mm), nonoperative treatment is recommended with an above knee case. However, if displacement > 2 mm, closed reduction can be performed with axial traction and internal rotation of the foot with the patient under general anaesthesia. Failure of closed reduction to achieve satisfactory position is an indication for open reduction and internal fixation.

Ertl et al. followed 23 children with triplane fractures, they found that favourable outcome was related to articular congruity of the weight bearing part of the distal tibia [76]. They found that residual displacement of 2 mm or more was associated with suboptimum result unless the epiphyseal fracture was outside the primary weight-bearing area of the ankle.

Another study of 35 children with triplane fractures who were followed up for more than 5 years reached the same conclusion; prognosis was good only when adequate reduction (< 2 mm displacement) had been achieved [77].

Weinberg et al. [78] in an evaluation of 50 children with triplane fractures, including 30 who had operative treatment and 20 who had non-operative treatment, reported that all

Table 22.7 Recommendations

Statement	Grade of recommendation
Stress views are not required to aid decision on treating undisplaced ankle fractures	B
CT scan should be requested in all physeal fractures	B/C
MRI scan is not routinely indicated in children ankle injury	C
Undisplaced ankle fracture in children can be safely treated non operatively	B
Displaced physeal and/ or intra-articular fracture should be reduced to anatomical position. Failure of closed reduction is an indication for open reduction	B
2 mm displacement is the threshold for reducing displaced fractures or accepting reduction as satisfactory	B/C
Above knee cast is better than below knee cast for physeal ankle injury	I

patients were doing well after a mean follow-up of 7.4 years. There were no significant differences between the group treated non-operatively and the group that underwent surgery. Only two of the initially undisplaced fractures later became displaced concluding that operative treatment is not indicated for all undisplaced fractures.

Recommendations for treatment are listed in Table 22.7.

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