17 Ankle and Foot: Acute Ligamentous Tears of the Ankle

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Ankle sprains are the most common type of acute sports trauma [1]. Epidemiologic studies revealed that ankle injury accounted for 14 % of all visitors to an emergency department [2] and for 11.4 % of children and adolescent population practicing sport activity [3]. In the past decade, improved biomechanics techniques have provided a better understanding of the mechanism of injury with consequent research into sports injury prevention and management [4].

The peak incidence of ankle sprain (7.2 per 1,000 person-years) occurs in patients between 15 and 19 years of age. Over half (53.5 %) of all ankle sprains occurred in individuals between 10 and 24 years old. The peak male incidence occurred between 15 and 19 years of age with an estimated incidence rate of 8.9 per 1,000 person-years, whereas females had a peak incidence between 10 and 14 years of age with an estimated incidence rate of 5.4 per 1,000 person-years [5].

Nearly half of all ankle sprains (49.3 %) occur during athletic activity, with basketball (41.1 %), football (9.3 %), soccer (7.9 %) being associated with the highest percentage of ankle sprains [5].

After an acute ankle inversion injury, a partial rupture of the anterior talo-fibular ligament (ATFL) or an isolated capsular lesion is present in 1 % of patients [6]. A rupture of both the ATFL and the calcaneofibular ligament (CFL) occurs in 15–25 % of cases. Isolated rupture of the CFL happens in approximately 1 % of patients. Injury to the posterior talo-fibular ligament is extremely rare [7]. Isolated ligament injuries of the deltoid ligament are also infrequent. Disruption of the ankle syndesmosis occurs in 1–5 % of patients after severe inversion trauma of the ankle. It is important to underline that the cartilage rim that covers the anterior distal tibia, the anterior part of the medial malleolus and the medial talar facet can be damaged by inversion trauma.

17.1 Anatomy

The ankle is a congruent joint composed of the tibia and fibula, both of which articulate with the talus. The talus is wide anteriorly and narrow posteriorly. This provides stability when the joint is in a neutral position, as the wider part of the talus is locked securely in the joint. Stability of the ankle is provided by both the bony configuration and by ligaments. Soft tissue stability is provided mainly by the deltoid ligament on the medial side and by the ATFL, the CFL, the posterior talo-fibular ligament, and the tibio-

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fibular syndesmosis superiorly on the lateral side [7, 8]. Dynamic stability is achieved by the peroneus brevis muscle laterally (everts the foot) and the tibialis posterior muscle medially (inverts the foot).

During ankle motion, rotation and translation around and along the movement axes occur. The ATFL is in a plane parallel to the axis of movement (flexion–extension) if the ankle is in a neutral position. This ligament, considered to be an intra-articular reinforcement of the joint capsule, is the main stabilizer on the antero-lateral aspect and is the most vulnerable to injuries [9]. Most ankle ligament injuries occur during internal rotation in the equinus position with the foot in plantar flexion, when the narrowest part of the talus is placed in the ankle mortise, so rendering the ankle the most lax. This is likely an important cause for the high prevalence of injuries of the ATFL [9–11].

The CFL originates from the anterior tip of the fibula and runs obliquely distally and posteriorly to attach to the lateral surface of the calcaneus. In some cases, the CFL attaches predominantly to the ATFL [7, 8]. In contrast to the ATFL, it is all extra-articular and separated from the fibrous capsule. The CFL is associated intimately with the postero-medial part of the peroneal tendon sheath and connects the talocrural and subtalar joints. The posterior talofibular ligament is a short, thick ligament that is tight when the ankle is in extension and lax during flexion. Injuries of this ligament are infrequent. The distal tibiofibular syndesmosis is essential for stability of the ankle mortise, and therefore for weight bearing and walking.

The main stabilizer on the medial side is the deep portion of the deltoid ligament. This ligament is fan-shaped, thick, strong, and infrequently injured. Anatomic variations in size, shape, orientation, and capsular relationship of the lateral ankle ligaments are common. Up to 75 % of subjects show some anatomic variations, most commonly of the CFL. The ATFL is divided into two separate bundles in one-third of patients. These anatomic variations should be considered when performing surgical reconstruction of ligaments [12].

17.2 Mechanism of Ankle Sprain Injury

Understanding the mechanism of injury is very important for prevention. Andersen et al. [13] reported that there were two major mechanisms of ankle inversion sprain: (1) impact by an opposing player on the medial aspect of the leg just before or at foot strike, resulting in a laterally directed force, causing the player to land with the ankle in a vulnerable inverted position; (2) forced plantar flexion when the injured player hits the opponent's foot when attempting to shoot or clear the ball. Both of these mechanisms ultimately led to rupture of the ATFL, as this ligament often sustains higher strain and strain rate values than the other ligaments in the antero-lateral ankle.

In a static cadaver study, Markolf et al. [14] reported that 41–45-Nm external rotatory torque would cause ankle failure, as defined by a major decline in torque as the foot continues to rotate, indicating a bony fracture or ligamentous rupture. However, only one quantitative investigation into ankle biomechanics during a real ankle sprain injury scenario was reported [15]. An accidental inversion sprain was analyzed, where the ankle sprain occurred in a laboratory with high-speed video capture. The ankle joint reached an inversion of 48° and an internal rotation of 10°.

A combination of forced external rotation, extension, and axial loading of the ankle causes a rupture of the ATFL [9, 10]. This can also be accompanied by a partial rupture of the deltoid ligament.

The mechanism of injury of the deltoid ligament is an excessive eversion. Injury of the ankle syndesmosis is often seen in soccer players after external rotation of the foot, in dancers after forced extension of the foot, and in alpine skiers after combined external rotation, axial compression, and forced extension [16, 17].

17.3 Classification of Acute Inversion Injuries

Many classifications have been proposed for acute sprains of the ankle and all were aimed at the research of the extent of the injury to then apply the most suitable treatment.

Ankle ligament injuries have been classified as grade I (mild), grade II (moderate), and grade III (severe) [18]. In grade I injuries, including stretching of the ligament, the loss of function is minimal and the anterior drawer and talar tilt tests are negative. In grade II injuries, there is a partial rupture of the ligaments, some loss of motion, and moderate dysfunction. Dynamic maneuvers are uncertain and there is moderate laxity. In grade III injuries, including complete rupture of the ligaments and joint capsule, there is major loss of function and reduction in motion, and dynamic maneuvers are uncertain in the acute presentation due to pain. Radiographs are often needed to rule out a fracture.

Some authors questioned the application of this classification system, as a partial rupture of the ATFL or isolated capsular lesion (grade I) is present in less than 1 % of cases after a supination injury [17] and studies show that there is no difference between the prognosis of single (grade II) or multiple (grade III) ligament ruptures [19]. However, it is important to distinguish an incomplete lesion of the ATFL without capsular damage from a complete ligament rupture, which is always associated with a capsular lesion of varying size.

Other systems for grading an acute ankle sprain have been proposed [20]. The two most basic systems are the anatomic system, which classifies the injury into three degrees based on the damaged ligaments, and the American Medical Association Standard Nomenclature System which considers the severity of the injury to the ligaments [21].

Davis and Trevino [22] presented a staging system that consisted of four grades, with some subgrading according to the pathology, the damage to the ligamentous structure and the instability, as presented clinically.

Mann et al. [20] proposed a system for practical clinical outpatient use. It is based on three parameters: pain, swelling, and inability to walk. Each parameter is rated 0–3 points (0 = none, 1 = mild, 2 = moderate, 3 = severe) and a total score is calculated: Grade I: 1–3 points, Grade II: 4–6 points, and Grade III: 7–9 points.

The various classifications proposed for acute presentation are not easy to apply. Clanton [21] suggested a system based on the treatment requested. This classification divides the injured ankle into categories of stable or unstable. The stable group is suggested to receive symptomatic treatment for pain relief. The unstable group is then divided into non-athletes (or older patients) and young active athletes. Non-athletes and older patients are suggested to receive functional treatment while the young active are suggested to receive primary surgical approach. Other authors divided skeletally immature patients into those with negative stress radiograph findings, those with positive tibio-talar stress radiograph findings, and those with subtalar instability. Those with positive tibio-talar instability are suggested to consider surgical repair of the lateral ligament complex [23, 24].

17.4 Diagnosis of Acute Inversion Injuries

The target of the diagnosis of an ankle inversion sprain is to differentiate the mild and moderate forms from severe cases to favor an adequate treatment [19]. While the therapy of a mild and moderate sprain is well defined and the conservative approach is treatment of choice, the therapy addressed to severe cases is subject to controversial. The first step is to differentiate the mild, moderate, and severe sprains. The acute mild injury is characterized by history: a minor trauma, mild swelling, the absence of hematoma, mild limping, and negative laxity tests (easy to evocate). The moderate or severe cases are clinically characterized by immediate similar signs history: acute pain with sensation of "craquement," marked limited function, patient limp and walks with aid of cannes, remarkable swelling (possibly the sign of “coquille d’oeuf” of Roberte-Jaspar [25]), pain on the antero-lateral aspect, and clinic ligamentous instability (difficult to evocate). Because of the reported poor reliability of physical examination for diagnosis of complete ligament ruptures with wide capsular involvement after inversion trauma of the ankle, stress radiography, arthrography, MRI, and ultrasonography (US) were utilized [24, 26–28]. Some of the instrumental methods are expensive, however, and their reliability is also debated. Physical examination is unreliable in the acute situation in moderate and severe cases because the anterior drawer test cannot be performed due to pain. The reliability of physical examination can be enhanced when repeated a few days after the trauma as determined in a series of 160 patients, all of whom underwent arthrography [29]. A few days after the trauma, the swelling and pain have subsided and it becomes obvious if the cause of swelling was edema or hematoma. The pain on palpation has become more localized, and the anterior drawer test can now be performed. Negative pain on palpation over the ATFL rules out acute lateral ligament rupture. However, positive pain on palpation over the ATFL cannot distinguish a complete rupture associated with wide capsular tear. Pain on palpation, in combination with bruising, has a 90 % chance of indicating an acute lateral ligament rupture. A positive anterior drawer test has a sensitivity of 73 % and a specificity of 97 %. A positive anterior drawer test, in combination with pain on palpation over the ATFL and bruising, has a sensitivity of 100 % and a specificity of 77 % [29]. A special mention must be to the observation of the presence of a complete tear of ATFL associated with an avulsion of the chondral or osteochondral fragment from the fibular malleolar apex or from the talus.

Few investigators have reported the incidence of avulsion fractures among mature patients with severe inversion injury. Broström [9, 30] reported it as 13 and 14 % in two different studies. The incidence of avulsion fracture was higher in a recent study [31] than in the Broström studies. This may be because avulsion fracture of the lateral malleolus is often misdiagnosed as ankle sprain or ligament rupture because the fragments are undetected on early plain radiographs [9, 32, 33].

Vahvanen et al. [33] found avulsion fragments in 19 of 40 sprained ankles in skeletally immature patients, 11 of which were not visible radiographically. Chaumien [34] reported 30 % of the avulsed fragment from the lateral malleolus in a series of 19 children and adolescents affected by acute severe inversion sprain. Busconi and Pappas [32] reported that in some skeletally immature patients, conventional radiographs often fail to show avulsion fragments. Broström [9] found intra-operatively that 11 of 90 ATFL injuries (13–14 % of cases) had avulsed fragments. Three of these were not radiographically visible. Schütze and Maas [35] investigated 130 pediatric patients with ligamentous rupture with or without osteochondral fragments who were treated surgically. In 37 % of these patients, they found an osteochondral fragment intra-operatively. One-third of these could not be seen radiographically. All of these investigators have assumed that most avulsed fragments are cartilaginous in skeletally immature patients and thus are not visible on traditional radiographs until they have ossified and enlarged.

Avulsion fracture from the lateral malleolus or from the talus may be misdiagnosed because the fragment is superimposed on the lateral malleolus in mature patients on early plain radiography. In skeletally immature patients, it may be totally cartilaginous and undetectable on radiographs [32, 35]. Physical examination alone does not provide a diagnostic modality for chondral or osteochondral avulsion fragments not detected by radiographs.

Therefore, there is some difficulty to recognize and to differentiate complete ATFL lesions from those coupled with wide capsular lesions, with avulsion fragments, that are unstable [28] and then defined as severe cases. Ultrasound examination (static and dynamic; during anterior drawer test, and talar tilt test) has to be considered for severe ankle sprain in skeletally immature patients to find the avulsion fragments

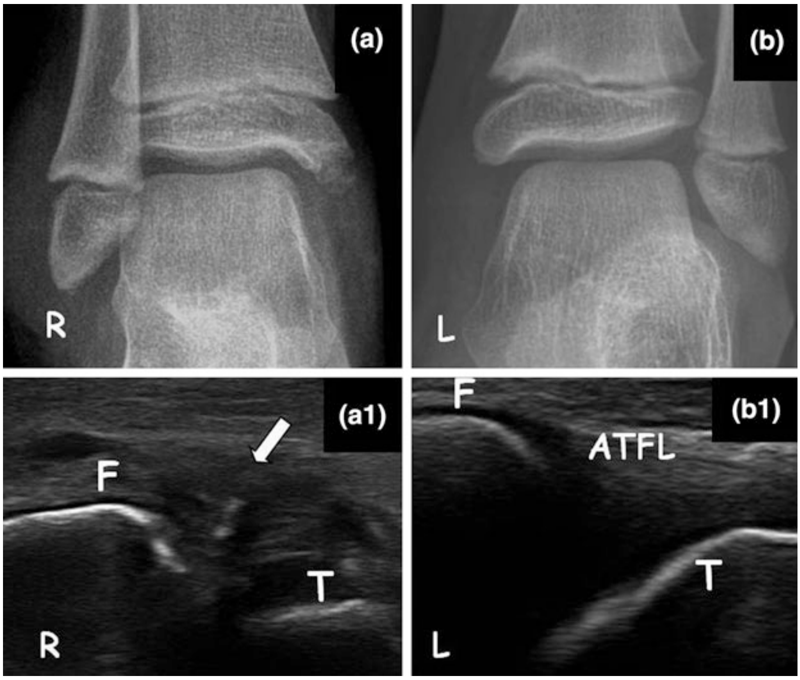

Fig. 17.1 X-Ray and static ultrasound evaluation of right ankle compared with the contralateral side. 11-year-old male. Fibula (*F*), talus (*T*), right (*R*), left (*L*), anterior talo-fibular ligament (*ATFL*). **a** X-ray of the *right* sprained ankle: radiolucency of the lateral soft tissue indicating swelling without evident signs of osteochondral avulsion. **b** X-ray of *left* non-affected ankle: normal radiographic imaging. **a1** Ultrasound of the *right* sprained ankle shows the presence of chondral avulsion from the fibula (*white arrow*) and the hematoma with an heterogenous mass where the capsular and the ATFL were injured. **b1** Ultrasound of the *left* non-affected ankle shows the normal ATFL appearance as an homogenous area between the fibula and talus

and evaluate the severity of capsular and ligament lesions [28, 32, 33, 36]. It must be underline that during the first 24–48 h after trauma, it is difficult to perform the dynamic maneuvers needed because of the pain and swelling. For these reasons, it is important to perform ultrasonographic examination at few days (3–5) after the acute trauma, to better evaluate the joint stability. In this way, it is possible to better define a stable lesion (moderate forms) from an unstable one [28, 32, 33, 36] (severe cases). The ultrasonographic sign of an introflexion of the damaged ATFL, of the capsule and, if present, of the avulsed fragment into the joint space is distinctive of an acute severe inversion sprain. The anatomic structures teared, and hematoma dip into the ankle joint through the wide capsular injury as the negative intra-articular pressure created by manual stress produces a vacuum effect (Figs. 17.1, 17.2).

Static and dynamic ultrasonography has a high sensitivity for diagnosing acute severe sprains associated with unstable ankle [28, 36, 37].

17.5 Treatment of Acute Inversion Injuries

Treatment of acute inversion sprains depends on the degree of the injury. Repeated studies and recent systematic reviews have shown that acute mild to moderate ankle sprains that include incomplete tear of the ligament or complete ligament tear with limited capsular injury and without avulsion fragments can be treated safely

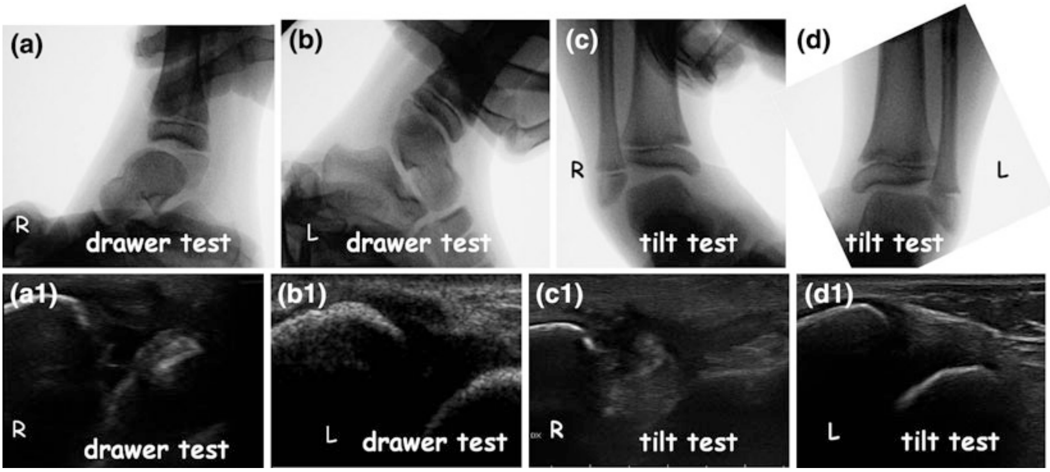

Fig. 17.2 The same patient of Fig. 17.1. X-ray and dynamic ultrasound evaluation of right sprained ankle compared with contralateral side executed under general anesthesia. **a** X-ray anterior drawer test of the *right* sprained ankle (>5 mm of anterior dislocation). **b** X-ray anterior drawer test of the *left* non-affected ankle (stable ankle). **a1** Dynamic US anterior drawer test of the *right* sprained ankle: the injured ATFL, capsule, and cartilaginous avulsed fragment deep into the joint. **b1** dynamic US evaluation of the *left* non-affected ankle does not show any abnormal images of ATFL and capsule. **c** X-ray talar tilt test of the *right* sprained ankle showing a value >10° of inclination. **d** X-ray talar tilt test of the *left* non-affected ankle does not show any abnormal degree of inclination value. **c1** Dynamic US talar tilt test of the *right* sprained ankle: the injured ATFL, capsule, and cartilaginous avulsed fragment deep into the joint. **d1** Dynamic US talar tilt test of the *left* non-affected ankle does not show any abnormal images of ATFL and capsule

with conservative treatment. Functional treatment with a short period of rest, cooling (ice), compression, and elevation to reduce edema (the RICE principle) during the first 1–3 days should always be recommended. Early weight bearing without crutches is encouraged. Active range of motion training should be started after the acute-phase treatment is completed,

The ankle rehabilitation program includes the returning to a normal range of motion associated with peroneal musculotendinous unit strengthening exercises to provide dynamic stability to the ankle combined with calf muscles and Achilles tendon exercises of flexibility to facilitate a neutral and more stable position of the ankle. Proprioceptive rehabilitation should be the final key. Deficit in proprioceptive rehabilitation has been shown to correlate with an increased incidence of ankle sprain [38], while proprioceptive exercises may decrease the risk of injury by almost 50 % [39]. Balance can be improved with exercises on wobble boards or small trampolines. The injured ligaments should be protected from new injuries during the healing phase by using external support to control the range of motion and to reduce the symptoms of functional instability. It is to remember that a gradual return to activity is dependent on progressive functional ability. One must walk before one may run, run before cut (change direction), and cut before being considered capable of playing. When all exercises are able to be carried out at full speed, return to play is allowed [40].

The results of functional treatment of these types of ankle sprains are satisfactory in most cases, and most athletes are able to return to sporting activities within a few weeks [27].

There is still controversy as to whether acute severe sprains, that is, complete tear of one or more ligaments with extensive capsular injury [21] ligament ruptures, should be treated non-surgically by active functional treatment and early mobilization, or with primary surgical

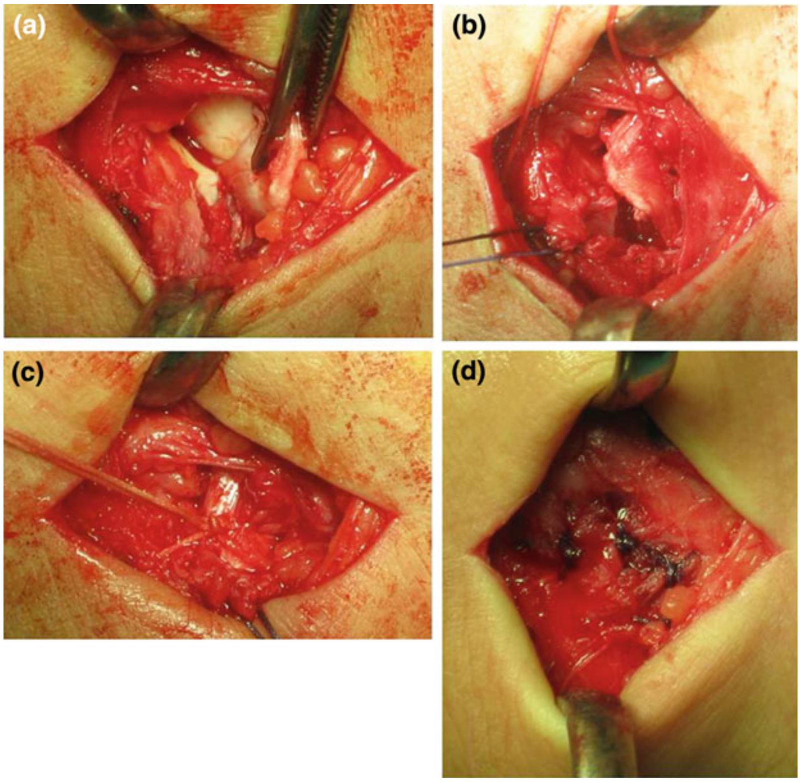

Fig. 17.3 The same patient of Figs. 17.1 and 17.2. **a** Operative findings: the cartilaginous avulsion fragment kept by Kocher clamp. **b**, **c**, and **d** Reinsertion by suture of the avulsed fragment on the fibular bone with reinforcement of capsular suture

repair followed by immobilization using a plaster cast or brace. Only a few prospective, randomized, controlled studies are found in the literature [41, 42]. A relatively recent meta-analysis concluded that surgical treatment leads to superior results in the short- and medium-term in athletes, in terms of the ankle giving way and residual pain. A large, randomized, prospective trial of surgical and functional treatment of lateral ankle ligament ruptures with 6–11 years of follow-up revealed that surgical treatment leads to less residual pain and giving way than functional treatment [43].

Complete ATFL lesions are generally associated with a wide capsular tear and produce potential chronic instability unstable lesions of the ankle joint in children [33] that can be associated with various features of chronic lateral impingement [21, 44]. Chronic instability in children is sustained by ankle laxity due to insufficiency of repaired fibrous tissue, loss of proprioception, and weakness of general tendons and is favored by constitutional ligamentous laxity, cavus foot, calcaneus varus, and varus tilt of the tarsal plafond. Moreover, repeated ankle sprains during growth risk to condition the perfect joint tarsal function as the talus morphology can be modified (Fig. 17.3a–e). Ultrasound investigation, in cases of acute inversion ankle sprain in skeletally immature patients, can help the physician to better assess the severity of the ligamentous lesion and can demonstrate a stable versus an unstable lesion. As written previously when introflexion of the ATFL and capsule into the joint is demonstrated by dynamic ultrasound, with anterior drawer and talar tilt tests, in particular especially during internal rotation, the lesion is to be considered unstable [45, 46].

In skeletally immature patients, it is important to perform a new dynamic evaluation after 3–5 days to better identify the presence of an avulsed unstable fragment that cannot be observed on radiographs. This evaluation can help determine an adequate form of treatment as

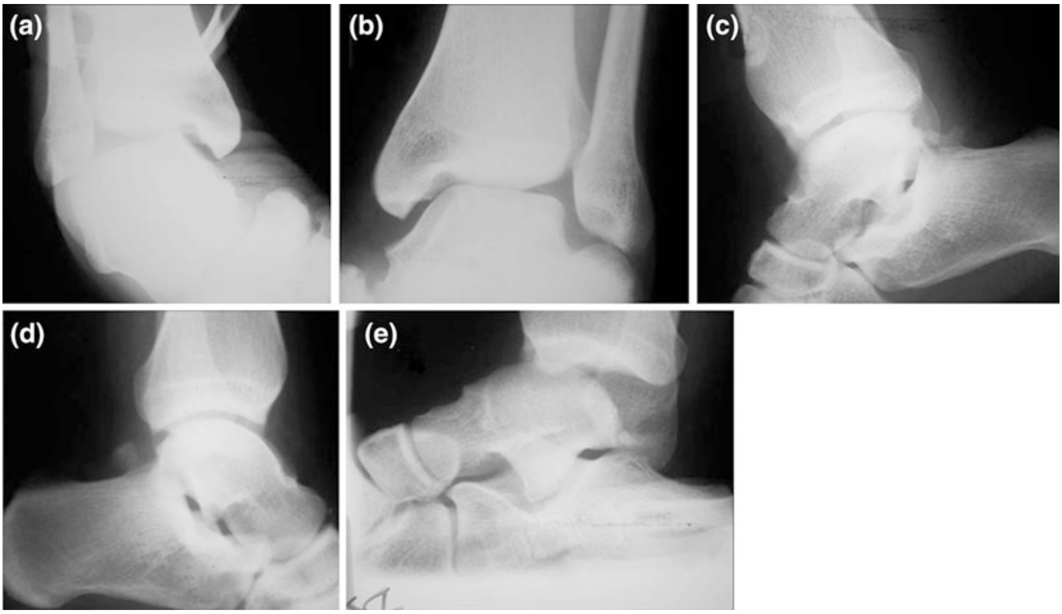

Fig. 17.4 Male of 18 yrs with chronic instability (Figs. 17.4a, e) secondary to ligament and capsule ruptures without avulsion fragment: first acute severe inversion sprain at 11 years of age and repeated sprains (twelve episodes) during 7 years. X-ray shows the abnormal talus morphology (Fig. 17.4c) if compared with non-affected side (Fig. 17.4b, d)

various authors have reported that unsatisfactory long-term results are due to the presence of avulsed fragments [32, 34]. For this reason, these lesions require surgical treatment [27, 33, 36].

As concern acute severe inversion sprains without avulsed fragments, surgical treatment can be adopted in skeletally immature patients when higher functional demands are required, or their activities necessitate perfect ankle function. Primary repair of the ligament with reconstruction of the normal anatomy even if debated offers the best resistance to the extra stresses imposed by sports activities [32, 33, 43] (Fig. 17.4) and can be considered one way to ensure a stable ankle in children with ligament rupture [33, 45, 46]. Despite the clinical and statistically significant superiority of surgical over functional treatment reported in case of acute severe ankle sprains [41], there are a number of reasons for questioning the routine use of surgery as the treatment of choice in non-athlete patients even if it is difficult to define the future choices of active children. First, delayed operative reconstruction of the injured ligaments has been reported to generate similar results compared with acute repair, even many years after the initial injury [12]. The decision to operate on every patient with an ankle ligament injury will increase the number of patients referred for surgery and impose an unacceptable strain on the available capacity of operating theaters. Operative treatment is also associated with much higher costs. In addition, surgery enhances the risk of complications such as infection, failure of wound healing, dystrophy, and nerve damage, even if these complications can be avoided by closely following the anatomic pathways and scrupulously applying all the rules of asepsis. However, the literature lacks of randomized trials, not retrospective, and recent comparing the results of the conservative and surgical treatment applied to acute severe sprains without avulsed fragment in non-athletic skeletally immature patients. The data obtained could improve the information from the studies existing [44, 46] and dated [28, 47]. Moreover, it is hopeful that the methods of the results detection are homogeneous. Kaikkonen et al.

[41] proposed a performance test protocol with a scoring scale, to evaluate functional recovery after ankle injury. The practical consisted of three questions on subjective assessment, two clinical measurements on the ankle, two muscle strength tests, one ankle functional stability test, and one balancing test. The total score correlated very well with the isokinetic strength test of the ankle, the subjective opinion about recovery and the subjective function assessment. Thus, this protocol is practical for clinical evaluation of ankle sprain injury. Bie et al. [36] derived an ankle functional scoring system that evaluated the pain, instability, weight bearing, swelling, and gait pattern, adding together for a score up to 100.

References

1. Fong DTP, Hong Y, Chan LK, Yung PSH, Chan KM (2007) A systematic review on ankle injury and ankle sprain in sports. Sports Med 37(1):73–94
2. Fong DTP, Man CY, Yung PSH, Cheung SY, Chan KM (2008) Sport-related ankle injuries attending an accident and emergency department. Injury 39(10):1222–1227
3. Zaricznyj B, Shattuck LJ, Mast TA, Robertson RV, D'Elia G (1980) Sports-related injuries in school-aged children. Am J Sports Med 8(5):318–324
4. Chan KM, Fong DTP, Hong Y, Yung PSH, Lui PPY (2008) Orthopaedic sport biomechanics: a new paradigm. Clin Biomech 23(1 Supp):21–30
5. Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ Jr (2010) The epidemiology of ankle sprains in the United States. J Bone Joint Surg 92A:2279–2284
6. Prins JG (1978) Diagnosis and treatment of injury to the lateral ligament of the ankle. A comparative clinical study. Acta Chir Scand Suppl 486:3–149
7. Golano′ P, Vega J, de Leeuw PAJ, Malagelada F, Manzanares MC, Gotzens V, van Dijk CN (2010) Anatomy of the ankle ligaments: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 18:557–569
8. Wiersman PH, Grifioen FMM (1992) Variations of three lateral ligaments of the ankle. A descriptive anatomical study. Foot 2:218–222
9. Brostrom L (1964) Sprained ankles. I. Anatomic lesions in recent sprains. Acta Chir Scand 128:483–495
10. Rasmussen O, Kromann-Andersen C (1983) Experimental ankle injuries. Analysis of the traumatology of the ankle ligaments. Acta Orthop Scand 54:356–362
11. Fallat L, Grimm DJ, Saracco JA (1998) Sprained ankle syndrome: prevalence and analysis of 639 acute injuries. J Foot Ankle Surg 37:280–285
12. Kannus P, Renstrfm P (1991) Treatment for acute tears of the lateral ligaments of the ankle. Operation, cast, or early controlled mobilization. J Bone Joint Surg 73A:305–312
13. Andersen TE, Floerenes TW, Arnason A, Bahr R (2004) Video analysis of the mechanisms for ankle injuries in football. Am J Sports Med 32(1 Supp):69–79
14. Markolf KL, Schmalzried TP, Ferkel RD (1989) Torsional strength of the ankle in vitro. The supination-external-rotation injury. Clin Orthop Rel Res 246:266–272
15. Fong DTP, Hong Y, Shima Y, Krosshaug T, Yung PSH, Chan KM (2009) Biomechanics of supination ankle sprain: a case report of an accidental injury event in laboratory. Am J Sports Med 37(4):822–827
16. Boytim MJ, Fischer DA, Neumann L (1991) Syndesmotic ankle sprains. Am J Sports Med 19:294–298
17. Taylor DC, Englehardt DL, Bassett FH III (1992) Syndesmosis sprains of the ankle. The influence of heterotopic ossification. Am J Sports Med 20:146–150
18. Konradsen L, Hflmer P, Sfndergaard L (1991) Early mobilizing treatment for grade III ankle ligament injuries. Foot Ankle 12:69–73
19. Van Dijk CN, Lim LS, Bossuyt PM et al (1996) Physical examination is sufficient for the diagnosis of sprained ankles. J Bone Joint Surg 78B:958–962
20. Mann G, Nysha M, Constantini N, Matan Y, Renstrom P, Lynch SA (2002) Mechanics of injury, clinical presentation, and staging. In: Nyska M, Mann G (eds) The uns table ankle human kinetics, pp 54–60
21. Clanton TO (1999) Athletic injuries to the soft tissues of the foot and ankle. In: Coughlin MJ, Mann RA (eds) Surgery of the foot and ankle. Mosby, St Louis, pp 1090–1209
22. Davis PF, Trevino S (1995) Ankle injuries. In: Baxter D (ed) The foot and ankle in sport. Mosby, St Louis, pp 147–169
23. Pijnenburg ACM, Bogaard K, Krips R, Marti RK, Bossuyt PM, van Dijk CN (2003) Operative and functional treatment of rupture of the lateral ligament of the ankle. A randomised, prospective trial. J Bone Joint Surg Br 85(4):525–530
24. van den Bekerom MPJ, Kerkhoffs GMMJ, McCollum GA, Calder JDF, van Dijk CN (2012) Management of acute lateral ankle ligament injury in the athlete. Knee Surg Sports Traumatol Arthrosc 21:1–6
25. Roberte-Jaspar A (1956) Severe sprains of the ankle. Acta Orthop Belg 22(2):132–136
26. Friedrich JM, Schnarkowski P, Rqbenacker S et al (1993) Ultrasonography of capsular morphology in normal and traumatic ankle joints. J Clin Ultrasound 21:179–187

27. Kerkhoffs GM, van den Bekerom M, Elders LAM et al (2012) Diagnosis, treatment and prevention of ankle sprains: an evidence-based clinical guideline. Br J Sports Med 46:854–860
28. Campbell DG, Menz A, Isaacs J (1994) Dynamic ankle ultrasonography: a new imaging technique for acute ankle ligament injuries. Am J Sports Med 22(6):855–858
29. van Dijk CN, Mol BW, Lim LS et al (1996) Diagnosis of ligament rupture of the ankle joint. Physical examination, arthrography, stress radiography, and sonography compared in 160 patients after inversion trauma. Acta Orthop Scand 67:566–570
30. Broström L (1965) Sprained ankles. III. Clinical observations in recent ligament ruptures. Acta Chir Scand 130:560–569
31. Naoki H, Hidekazu T, Nobumasa S, Fumio K (2007) Avulsion fracture of the lateral ankle ligament complex in severe inversion injury. Incidence and clinical outcome. Am J Sports Med 35:1144–1152
32. Busconi BD, Pappas AM (1996) Chronic, painful ankle instability in skeletally immature athletes. Ununited osteochondral fractures of the distal fibula. Am J Sports Med 24:647–651
33. Vahvanen V, Westerlund M, Nikku R (1984) Lateral ligament injury of the ankle in children. Follow-up results of primary surgical treatment. Acta Orthop Scand 55:21–25
34. Chaumien JP, Rigault P, Touzet P, Padovani JP (1986) Severe sprains of the ankle in children and adolescents. Rev Chir Orthop Rep Appar Mot 72(2):56–62
35. Schütze F, Maas U (1989) Osteochondral involvement in fibulotalar ligament ruptures. Z Kinderchir 44:91–93
36. de Bie RA, de Vet HC, Wildenberg FA, Lenssen FA, Knipschild PG (1997) The prognosis of ankle sprains. Int J Sports Med 18(4):285–289
37. Simanovsky N, Hiller N, Leibner E, Simanovsky N (2005) Sonographic detection of radiographically occult fractures in paediatric ankle injuries. Pediatr Radiol 35:1062–1065
38. Mcgiune TA, Greene JJ, Best T, Leverson G (2000) Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med 10:239–244
39. Bahr R, Lian O, Barh IA (1997) A twofold reduction in the incidence of acute ankle sprains in volleyball after the injury prevention program: a prospective cohort study. Scand J Med Sci Sport 7(3):172–177
40. Stanitski CL (1988) Management of sports injuries in children and adolescents. Orthop Clin North Am 19(4):689–698
41. Munk B, Holm-Christensen K, Lind T (1995) Long-term outcome after ruptured lateral ankle ligaments. A prospective study of three different treatments in 79 patients with 11-year followup. Acta Orthop Scand 66:452–454
42. Povacz P, Unger SF, Miller WK et al (1998) A randomized, prospective study of operative and nonoperative treatment of injuries of the fibular collateral ligaments of the ankle. J Bone Joint Surg 80A:345–351
43. Kaikkonen A, Kannus P, Jarvinen M (1994) A performance test protocol and scoring scale for the evaluation of ankle injuries. Am J Sports Med 22(4):462–469
44. Meislin RJ, Rose DJ, Parisien JS, Springer S (1993) Arthroscopic treatment of synovial impingement of the ankle. Am J Sports Med 21(2):186–189
45. Guzzanti V (2001) Ankle ligament injuries in children. Fourth international pediatric orthopedic symposium. Orlando, USA, pp 586–587
46. Guzzanti V, Falciglia F (2012) Lesioni capsulo-legamentose acute della tibio-tarsica nell'adolescente. G.I.O.T. 37(Supp 1):S224–S229
47. Guzzanti V, Di Lazzaro A, Falciglia F (1997) Le distorsioni della tibio-peroneo-astragalica in età evolutiva. G.I.O.T. suppl. vol. XXIII fasc.3 ott.1997:483–486
48. Tol JL, Verheyen CP, van Dijk CN (2001) Arthroscopic treatment of anterior impingement in the ankle. J Bone Joint Surg 83B:9–13