BRITISH JOURNAL OF HOSPITAL MEDICINE

Assessment and management of adult ankle fractures: understanding the evidence

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Abstract

Ankle fractures are a common injury. Assessment should include looking at the mechanism of injury, comorbidities, associated injuries, soft tissue status and neurovascular status. Emergent reduction is required for clinically deformed ankles.

Investigations should include plain radiographs and a computed tomography scan for more complex injuries or those with posterior malleolus involvement. An assessment of ankle stability determines treatment, taking into account comorbidities and preoperative mobility which need special consideration. Non-operative management includes splint or cast, allowing for early weightbearing when the ankle is stable.

Operative management includes open reduction and internal fixation, intramedullary nailing (of the fibula and hindfoot) and external fixation. Syndemosis stabilisation includes suture button or screw fixation. The aim of treatment is to restore ankle stability and this article explores the current evidence in best practice.

Key words: Ankle; BOAST; Falls; Fracture; Trauma

Submitted: 24 July 2020; accepted following double-blind peer review: 11 December 2020

Introduction

Ankle fractures account for 9% of all fractures (Court-Brown and Caesar, 2006), with an increasing incidence in older women (Kannus et al, 2002). Often the mechanism of injury is low energy and rotational, from a simple fall or a sports injury (Court-Brown et al, 1998). Fractures may affect one or more of the bones that form the ankle joint and can be classified as unstable or stable. The most prevalent are unimalleolar fractures, accounting for 70% of all ankle fractures (Court-Brown and Caesar, 2006).

This article gives overview of ankle fracture treatment in adults, based on the British Orthopaedic Association Standards for Trauma and Orthopaedics (BOAST) Guidelines published by the British Orthopaedic Association (BOA) (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016; National Institute for Health and Care Excellence, 2016).

Clinical anatomy

The ankle joint can be thought of as a 'ring', which consists of bony structures (fibula and tibia) and ligamentous structures (deltoid ligament, lateral ligament complex and distal tibiofibular syndesmosis). The joint is formed around the talus, which contributes to its overall stability. The lateral ligament complex consists of the anterior talofibular ligament, calcaneofibular ligament and posterior talofibular ligament. The distal tibiofibular syndesmosis links the distal tibia and fibula with a ligament complex: a thickened portion of the interosseous membrane called the interosseous ligament, the inferior transverse ligament, the anterior inferior tibiofibular ligament and the posterior inferior tibiofibular ligament.

Syndesmosis stability relies on bony/ligamentous integrity. The fibula articulates with the lateral tibia in a groove called the incisura tibialis. If the ring is disrupted at one site (bony or ligamentous injury), the ankle joint remains stable; disruption at two or more sites leads to instability. Under physiological stress, stable fractures do not displace the syndesmosis, but unstable fractures displace, with subluxation of the talus. Displacement of 1 mm results in 40–42% reduction in the contact area of the tibiotalar joint (Lloyd et al, 2006), leading to early arthritis. Wang et al (2016) proposed that the ankle can be divided

How to cite this article:
Yip G, Hay D, Stringfellow T, Ahluwalia A, Ahluwalia R. Assessment and management of adult ankle fractures: understanding the evidence. Br J Hosp Med. 2021. https://doi.org/10.12968/hmed.2020.0445

Table 1. Columns of the ankle
The lateral column consists of the fibula and lateral ligaments
The middle column consists of the tibia, the syndesmotic ligaments and the interosseous ligaments
The medial column consists of the medial malleolus (tibia) and deltoid ligament, which has superficial and deep components

adapted from Wang et al (2016)

Table 2. Danis–Weber classification and AO-OTA classification

Weber	AO-OTA classification	AO-OTA sub-layer
A	Type A: infra-syndesmotic	
B	Type B: trans-syndesmotic	B1: trans-syndesmotic + medial structures intact
		B2: trans-syndesmotic + medial structures injured
C	Type C: supra-syndesmotic	

into three columns – lateral, middle and medial, as shown in Table 1 – and suggested fixation of two out of three of the columns stabilises the ankle mortice. Medial column integrity, and in particular the deep deltoid ligament, is key to stability of the ankle joint (Lampridis et al, 2018). The deep deltoid ligament acts as a check rein to talar displacement, even with lateral malleolus displacement (Harper, 1995) or syndesmosis injury (Boden et al, 1989). Physiological or axial loading enhances stability provided the deep deltoid ligament is intact, as the talus is pushed into congruence (Boruta et al, 1990). The widest part of the talus engages in the tibiotalar joint with the foot in neutral dorsiflexion and is the most stable position (Smith and Reischl, 1988).

Classification

There are three common classifications used: Lauge–Hansen, Danis–Weber and the AO classifications. The Danis–Weber and AO-OTA classifications are similar, describing the anatomy of fracture of the lateral malleolus in relation to the syndesmosis. The AO-OTA classification adopted the Danis–Weber classification and has two sub-layers, which define presence or absence of an injury in the medial structures (Table 2 and Figure 1). The boundaries of the distal tibiofibular syndesmosis are defined as an area of the origins and attachments of the tibiofibular ligaments (Kelikian and Kelikian, 1985). The Lauge–Hansen classification (Table 3) is based on position of the foot at time of injury, along with the direction of the deforming force. This classification is useful to understand how to reduce the fracture, but it does not predict ankle instability.

Patient assessment

Mechanism of injury

The majority of injuries result from low energy, rotational trauma such as a simple fall from standing height. Sports injuries are the second most common. Higher energy trauma causes include falls from a height or road traffic accident (Court-Brown and Caesar, 2006). A detailed history should be documented at presentation. Certain factors may influence management choice and outcome (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016) (Table 4).

Initial assessment and examination

Patients should be initially assessed and managed with Advanced Trauma Life Support guidelines. Open fractures should be managed in accordance with the BOA/BAPRAS guidelines for open fractures (British Orthopaedic Association and British Association of

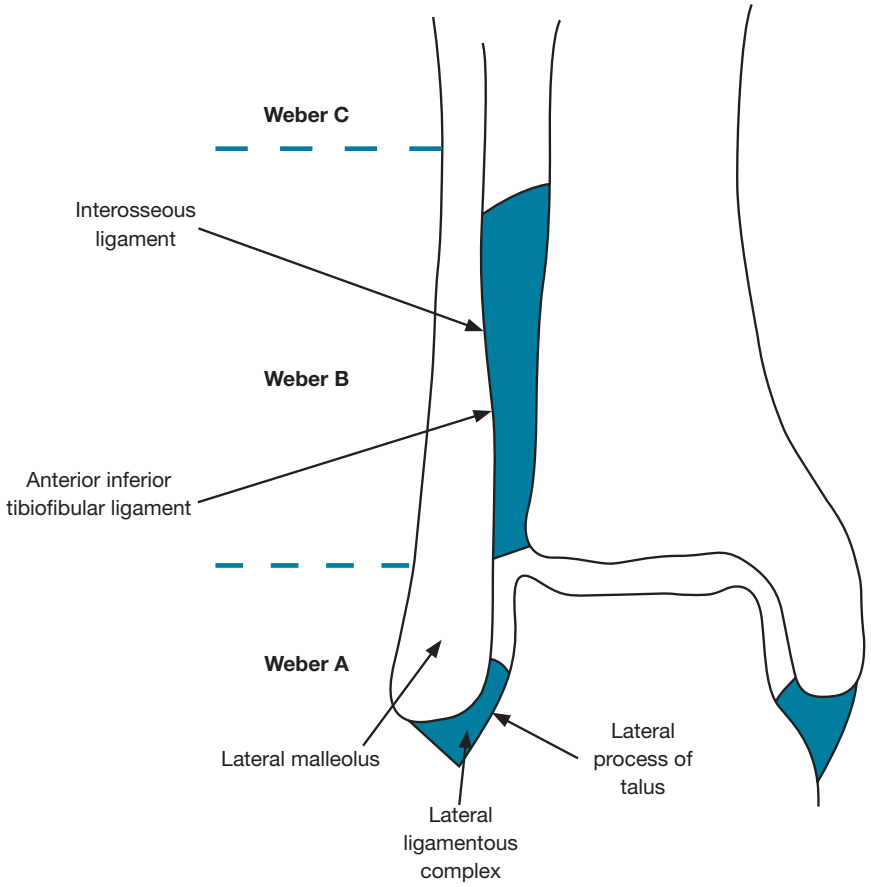

Figure 1. Danis–Weber and AO-OTA classifications.

Table 3. Lauge–Hansen classification

Type	Stages
Supination-external rotation	Stage 1: Anterior inferior tibiofibular ligament rupture
	Stage 2: Spiral fracture of fibula
	Stage 3: Posterior inferior tibiofibular ligament rupture or avulsion fracture posterior malleolus
	Stage 4: Medial malleolus fracture (transverse) or deltoid ligament rupture
Supination-adduction	Stage 1: Lateral ligament injury or transverse ligament fracture at or below level of anterior inferior tibiofibular ligament
	Stage 2: Oblique or vertical fracture of medial malleolus
Pronation-external rotation	Stage 1: Medial malleolus fracture
	Stage 2: Anterior lip of tibial plafond fracture
	Stage 3: Oblique fibula fracture above level of syndesmosis
	Stage 4: Posterior inferior tibiofibular ligament rupture or avulsion fracture posterior malleolus
	Slight syndesmosis widening
Pronation-abduction	Stage 1: Deltoid ligament rupture or medial malleolus fracture
	Stage 2: Anterior inferior tibiofibular ligament rupture or avulsion fracture anterolateral tibia
	Stage 3: Transverse or comminuted fibula fracture above level of syndesmosis
	Stage 4: Posterior inferior tibiofibular ligament rupture or avulsion fracture posterior malleolus
	Obvious syndesmosis disruption

Table 4. Factors that influence treatment choice

Factor		Explanation
Mechanism, location, time		Highly contaminated wounds in open fractures (agriculture, sewage, marine) – requires immediate debridement (British Orthopaedic Association and British Association of Plastics and Reconstructive Surgeons, 2017)
Comorbidities	Diabetes mellitus	Increased risk of complications – deep infection, wound complications, loss of reduction, non-union, hardware failure
	Peripheral vascular disease	
	Peripheral neuropathy	
	Osteoporosis	
	Renal disease	Influences treatment option, eg length of immobilisation, mode of surgical fixation
Social history	Mobility impairment	
	Smoking, alcohol use	

From British Orthopaedic Association and British Orthopaedic Foot and Ankle Society (2016)

Plastics and Reconstructive Surgeons, 2017), with transfer to a specialist centre with an orthoplastics service. The examination should include:

- Ankle, knee and foot
- Inspection for gross dislocation/deformity – eg foot position/direction
- Skin integrity – bruising, swelling, wounds, skin at risk under tension
- A full neurovascular assessment – documented before there is any attempt of fracture reduction
- Location of pain – may indicate uni or bi-malleolar injury, high fibula fracture, soft tissue injury
- Inability to weight bear.

One should note that medial-sided tenderness does not correlate with deep deltoid ligament injury (DeAngelis et al, 2007).

Imaging

The Ottawa Ankle Rules are used to determine the need for radiographs in a suspected ankle fracture (National Institute for Health and Care Excellence, 2016). Radiographs should be centred on the ankle, including a mortice (15–20° internal rotation) and true lateral view (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016). Normal parameters of an ankle radiograph range widely (Figure 2 and Table 5), and comparison with the contralateral ankle is useful. Abnormalities suggesting instability are key and described in Table 5. Where stability of the fracture is uncertain, the patient should be reassessed within 7–10 days with weight-bearing radiographs to assess for stability when pain settles (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016; National Institute for Health and Care Excellence, 2016). Weight-bearing X-rays are commonly used as a dynamic/physiological test in lateral malleolus fractures to assess integrity of the deep deltoid ligament (Lampridis et al, 2018). Gravity stress views can overestimate the medial clear space as the foot tends to be plantarflexed, and not as accurate as weight-bearing views (Seidel et al, 2017).

Additional plain radiographs of the whole leg may be indicated, should clinical examination suggest a proximal third fibula fracture. This type of fracture would indicate a Maisonneuve injury (proximal fibula fracture associated with disruption to the interosseous membrane and distal tibiofibular syndesmosis). As clinically indicated, knee and/or foot radiographs may also be necessary (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016). In more complex fractures, with comminution and involvement of the posterior malleolus, a computed tomography scan would be useful to give more details of the fracture pattern and aid surgical planning (Kumar et al, 2018).

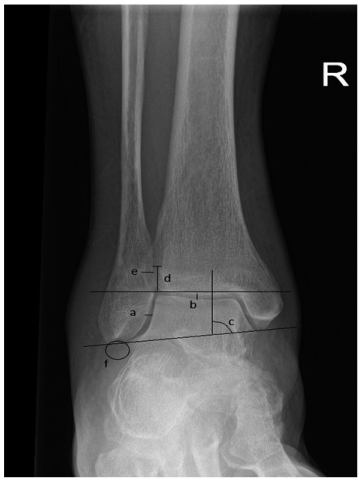

Figure 2. Ankle mortice radiograph with normal measurements.

Table 5. Radiographic features of a normal ankle and abnormalities associated with an unstable fracture

Normal radiographic measurements	Medial clear space ≤4 mm. This is the distance between the medial malleolus and medial talus with the foot in neutral
	Superior clear space and medial clear space <1–2 mm difference
	Talar tilt <2 mm
	Talocrural angle 83° (+/-4°)
	Syndesmosis-tibial clear space ≤5 mm. This is the distance between the tibia and fibula, measured at 1cm above the tibial plafond
	Tibiofibular overlap ≥10 mm or 42% width of fibula on anterior-posterior views, and ≥1 mm on mortice views
	Continuous curve of distal fibula with the lateral talus
Radiographic features of an unstable fracture	Talar displacement
	Increased medial clear space >4 mm
	Syndesmosis widening

Management

Ankle stability determines choice of treatment (Lampridis et al, 2018). Management follows best practice guidelines, eg the British Orthopaedic Association Standards for Trauma and Orthopaedics, factoring in injury pattern, ankle stability and patient-related factors (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016).

Emergent reduction

Clinically deformed fractures require emergent reduction and splinting to prevent skin necrosis, which could lead to an open fracture and reduces risk of neurovascular compromise. Radiographs should be obtained before reduction, but it is not necessary if this will cause an unacceptable delay (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016).

Reduction should ideally be performed in the emergency department with analgesia and sedation. The aim is to manipulate the talus back to its anatomical position under the tibia. With the hip and knee flexed, the reduction manoeuvre consists of axial traction, by grasping the calcaneum and midfoot and reversing the deforming forces described by Lauge–Hansen. The ankle should be splinted in a neutral position, with a below knee back-slab. Following

reduction, neurovascular assessment should be repeated and documented. Adequate reduction should be confirmed with repeat radiographs and then documented (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016).

Stable ankle fractures: non-operative management

Ankle fractures deemed to be stable and not likely to displace can be managed non-operatively, with analgesia, splinting and weight bearing. A walking boot or full below-knee walking cast is used for 6 weeks and follow up may not be necessary. For those with poor bone quality or peripheral neuropathy, eg diabetes, management should be non-weightbearing with cast immobilisation in a well-padded closed contact cast and close supervision. Stability must be monitored and if deemed unstable, surgical evaluation is required urgently. Isolated un-displaced medial malleolus fractures can be managed non-operatively in cast (Herscovici et al, 2007). However, assessment for a Maisonneuve injury with syndesmotic disruption needs to be ruled out.

Unstable ankle fractures

Operative management is suggested when the ankle mortice is unstable, in the majority of younger patients. Early fixation is recommended on the day or the next day after the injury occurs (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016). The aim of surgery is to reduce and stabilise the ankle mortice. In cases of gross instability and/or soft tissue compromise, external fixation may be recommended for temporary stabilisation before definitive surgery (British Orthopaedic Association and British Orthopaedic Foot and Ankle Society, 2016).

Operative techniques

Open reduction and internal fixation should follow AO principles of fracture fixation (Buckley et al, 2018). This is generally with plate fixation of the lateral malleolus. Transverse medial malleolus fractures are stabilised with parallel screws or a tension band construct if the fragment is too small for screws. More vertical fractures may require an anti-glide plate.

Syndesmosis

The stability of the syndesmosis should be assessed intraoperatively. Fixation can then be undertaken as necessary after bony fixation. The ankle is stressed by external rotation and valgus force (the Cotton test) or intraoperatively by direct pull on the fibula in the coronal plane with the ‘hook test’. The intraoperative radiographs demonstrate loss of tibiofibular overlap. Sagittal plane instability also needs to be assessed as the fibula tends to be most unstable in this plane (Buckley et al, 2018).

The fibula is anatomically reduced back into the incisura, assessed with fluoroscopy and also by direct visualisation over the anterior inferior tibiofibular ligament. Stabilisation is achieved with a positional screw(s) into the tillaux or avulsion fragment of the anterior inferior tibiofibular ligament or syndesmosis suture button(s)/screw fixation. This can be placed through the fibular plate following bony fixation. Isolated syndesmosis fixation can be performed in Maisonneuve injuries or high fibula fractures, where the fibula length is maintained. Evidence favours suture button fixation in suitable patients, as it results in better functional score, earlier return to work, as well as a lower rate of implant removal, implant failure and malreduction (Naqvi et al, 2012; Zhang et al, 2017).

Posterior malleolus

The posterior inferior tibiofibular ligament is attached to the posterior malleolus, providing 40% of the resistance to talus lateral translation (Ogilvie-Harris et al, 1994). Fixation of the displaced posterior malleolus stabilises the syndesmosis, with greater stability than trans-syndesmotic fixation (Bartoníček et al, 2017). A total of 70% of syndesmosis stiffness is achieved after posterior malleolus fixation, compared to 40% with trans-syndesmotic screws (Gardner et al, 2006). Fixation of the posterior malleolus fragment is recommended if it involves ≥25% of the articular surface (Odak et el, 2016). Reported fixation of the posterior malleolus fragment is required if ≥10% of the articular surface is affected with residual joint incongruency following fixation of the lateral and medial

structures. Posterolateral and posteromedial approaches are used to allow an anti-glide plate or lag screw fixation of the posterior malleolus; plating shows better stability than screws (Bennett et al, 2016).

Special considerations

For individuals over 60 years old, closed constant casting can be offered if reduction can be maintained. The AIM trial, a UK multi-centre randomised control trial, showed those >60 years old with acute unstable ankle fractures, treated with closed constant casting had equivalent function outcomes to those treated with open reduction and internal fixation at 6 months follow up (Willett et al, 2016). In osteoporotic bone, options to achieve stability require robust implant constructs including locking plates and fibula-pro-tibia screws (Kim et al, 2007; Panchbhavi et al, 2009). For complex fractures in patients with comorbidities (eg elderly patients) at risk of perioperative infection, soft tissue compromise or osteoporotic bone, open reduction and internal fixation carries a higher risk of complication. Therefore, primarily minimally invasive techniques with a fibula or hindfoot intramedullary nail can be considered, which would allow early weight bearing (Al-Nammari et al, 2014; Georgiannos et al, 2017). Hindfoot nails are more suitable for those with lower baseline mobility as ankle and subtalar joint motions are sacrificed.

Postoperative care and follow up

Most patients should be allowed to weight bear after operative fixation, in a splint or cast, unless there is concern regarding stability of the fixation or other contraindications. These may include peripheral neuropathy or soft tissue issues. Venous thromboembolism assessment should be made for all patients and prophylaxis prescribed as per local protocols. Follow up is made in the fracture clinic within 6 weeks to monitor for maintained reduction with radiographs and to detect any complications.

For all patients, whether management is operative or non-operative, information on expected recovery and rehabilitation protocol should be given. This should include information on expected return to normal activities such as work and driving. A system for self-referral back to fracture services should be in place if anticipated recovery is not achieved.

Conclusions

Assessment of ankle stability determines treatment, taking into account comorbidities and preoperative mobility, which need special consideration. Early return to weight-bearing can be achieved with the restoration of ankle stability.

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Key points

- Ankle fractures are common, accounting for 9% of all fractures.
- Assessment of ankle stability is key to determining management. Generally, unstable fractures require operative stabilisation.
- Clinically deformed ankle fractures require emergent reduction in the emergency department. Treatment should not be delayed while waiting for radiographs.
- Early weightbearing should be allowed in patients with stable ankle fractures.
- The aim of treatment is to restore a stable congruent ankle mortice.

Curriculum checklist

This article covers the requirements of the trauma and orthopaedic curriculum regarding:

- Ankle fractures
- Anatomy of the foot and ankle and related structures
- Radiological investigations to assess foot and ankle conditions
- History and examination of the foot and ankle including special clinical tests
- Ankle fracture fixation
- Rehabilitation of the foot and ankle

Conflicts of interest

The authors declare that they have no conflicts of interest.

References

Al-Nammari SS, Dawson-Bowling S, Amin A, Nielsen D. Fragility fractures of the ankle in the frail elderly patient: treatment with a long calcaneotalotibial nail. Bone Jt J. 2014;96-B(6):817–822. https://doi.org/10.1302/0301-620X.96B6.32721

Bartoníček J, Rammelt S, Tuček M. Posterior malleolar fractures: changing concepts and recent developments. Foot Ankle Clin. 2017;22(1):125–145. https://doi.org/10.1016/j.fcl.2016.09.009

Bennett C, Behn A, Daoud A et al. Buttress plating versus anterior-to-posterior lag screws for fixation of the posterior malleolus: a biomechanical study. J Orthop Trauma. 2016;30(12):664–669. https://doi.org/10.1097/BOT.0000000000000699

Boden SD, Labropoulos PA, Mccowin P, Lestini WF, Hurwitz SR. Mechanical considerations for the syndesmosis screw. A cadaver study. J Bone Joint Surg Am. 1989;71(10):1548–1555

Boruta PM, Bishop JO, Braly WG, Tullos HS. Acute lateral ankle ligament injuries: a literature review. Foot Ankle Int. 1990;11(2):107–113. https://doi.org/10.1177/107110079001100210

British Orthopaedic Association and British Association of Plastics and Reconstructive Surgeons. British Orthopaedic Association Standards for Trauma - open fractures. 2017. https://www.boa.ac.uk/uploads/assets/3b91ad0a-9081-4253-92f7d90e8df0fb2c/29bf80f1-1cb6-46b7-afc761119341447f/open%20fractures.pdf (accessed 12 April 2021)

British Orthopaedic Association and British Orthopaedic Foot and Ankle Society. British Orthopaedic Association Standards for Trauma - the management of ankle fractures. 2016. https://www.boa.ac.uk/uploads/assets/f8b1c499-c38a-4805-8cb8d8eb3087bca7/8be763eb-5921-4cb2-b6802f3e65ce8e7f/the%20management%20of%20ankle%20fractures.pdf (accessed 12 April 2021)

Buckley R, Moran C, Apivatthakakul T. AO principles of fracture management. 3rd edn. Thieme; 2018

Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury. 2006;37(8):691–697. https://doi.org/10.1016/j.injury.2006.04.130

Court-Brown CM, McBirnie J, Wilson G. Adult ankle fractures--an increasing problem? Acta Orthop Scand. 1998;69(1):43–47. https://doi.org/10.3109/17453679809002355

DeAngelis NA, Eskander MS, French BG. Does medial tenderness predict deep deltoid ligament incompetence in supination-external rotation type ankle fractures? J Orthop Trauma. 2007;21(4):244–247. https://doi.org/10.1097/BOT.0b013e3180413835

Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorich DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. Clin Orthop Relat Res. 2006;447(447):165–171. https://doi.org/10.1097/01.blo.0000203489.21206.a9

Georgiannos D, Lampridis V, Bisbinas I. Fragility fractures of the ankle in the elderly: open reduction and internal fixation versus tibio-talo-calcaneal nailing: short-term results of a prospective randomized-controlled study. Injury. 2017;48(2):519–524. https://doi.org/10.1016/j.injury.2016.11.017

Harper MC. The short oblique fracture of the distal fibula without medial injury: an assessment of displacement. Foot Ankle Int. 1995;16(4):181–186. https://doi.org/10.1177/107110079501600402

Herscovici D, Scaduto JM, Infante A. Conservative treatment of isolated fractures of the medial malleolus. J Bone Jt Surg - Ser B. 2007;89-B(1):89–93. https://doi.org/10.1302/0301-620X.89B1.18349

Kannus P, Palvanen M, Niemi S, Parkkari J, Jrvinen M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970-2000 and projections for the future. Bone. 2002;31(3):430–433. https://doi.org/10.1016/S8756-3282(02)00832-3

Kelikian H, Kelikian AS. Disorders of the ankle. Philadelphia (PA): W.B. Saunders Company; 1985:4–8

Kim T, Ayturk UM, Haskell A, Miclau T, Puttlitz CM. Fixation of osteoporotic distal fibula fractures: a biomechanical comparison of locking versus conventional plates. J Foot Ankle Surg. 2007;46(1):2–6. https://doi.org/10.1053/j.jfas.2006.09.009

Kumar A, Mishra P, Tandon A, Arora R, Chadha M. Effect of CT on management plan in malleolar ankle fractures. Foot Ankle Int. 2018;39(1):59–66. https://doi.org/10.1177/1071100717732746

Lampridis V, Gougoulias N, Sakellariou A. Stability in ankle fractures: diagnosis and treatment. EFORT Open Rev. 2018;3(5):294–303. https://doi.org/10.1302/2058-5241.3.170057

Lloyd J, Elsayed S, Hariharan K, Tanaka H. Revisiting the concept of talar shift in ankle fractures. Foot Ankle Int. 2006;27(10):793–796. https://doi.org/10.1177/107110070602701006

Naqvi GA, Cunningham P, Lynch B, Galvin R, Awan N. Fixation of ankle syndesmotic injuries: comparison of tightrope fixation and syndesmotic screw fixation for accuracy of syndesmotic reduction. Am J Sports Med. 2012;40(12):2828–2835. https://doi.org/10.1177/0363546512461480

National Institute for Health and Care Excellence. Fractures (non-complex). NICE guideline NG38. 2016. https://www.nice.org.uk/guidance/ng38/evidence (accessed 29 March 2021)

Odak S, Ahluwalia R, Unnikrishnan P, Hennessy M, Platt S. Management of posterior malleolar fractures: a systematic review. J Foot Ankle Surg. 2016;55(1):140–145. https://doi.org/10.1053/j.jfas.2015.04.001

Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. Arthroscopy. 1994;10(5):558–560. https://doi.org/10.1016/S0749-8063(05)80014-3

Panchbhavi VK, Vallurupalli S, Morris R. Comparison of augmentation methods for internal fixation of osteoporotic ankle fractures. Foot Ankle Int. 2009;30(7):696–703. https://doi.org/10.3113/FAI.2009.0696

Seidel A, Krause F, Weber M. Weightbearing vs gravity stress radiographs for stability evaluation of supination-external rotation fractures of the ankle. Foot Ankle Int. 2017;38(7):736–744. https://doi.org/10.1177/1071100717702589

Smith RW, Reischl S. The influence of dorsiflexion in the treatment of severe ankle sprains: an anatomical study. Foot Ankle Int. 1988;9(1):28–33. https://doi.org/10.1177/107110078800900106

Wang C, Huang S, Sun X et al. Clinical application of three-column theory to tibiofibular syndesmosis injury after ankle fractures. Int J Clin Exp Med. 2016;9(3):5517–5524

Willett K, Keene DJ, Mistry D et al. Close contact casting vs surgery for initial treatment of unstable ankle fractures in older adults a randomized clinical trial. JAMA - J Am Med Assoc. 2016;316(14):1455–1463. https://doi.org/10.1001/jama.2016.14719

Zhang P, Liang Y, He J et al. A systematic review of suture-button versus syndesmotic screw in the treatment of distal tibiofibular syndesmosis injury. BMC Musculoskelet Disord. 2017;18(1):286. https://doi.org/10.1186/s12891-017-1645-7