

# Current Concepts Review: Ankle Fractures

## Zlomeniny hlezna – přehled současných přístupů

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### SUMMARY

Ankle fractures are common injuries that require meticulous technique in order to optimise outcome. The Lauge-Hansen and Danis-Weber classifications in addition to careful evaluation of the injury mechanism can help guide treatment but surgeons must be aware that there are injury patterns that will not always fit the afore mentioned patterns. The principles of atraumatic soft tissue handling, rigid internal fixation and early range of motion exercises are critical for successfully treating these injuries. There are still areas of treatment uncertainty and future directed research is needed in order to address some of these questions.

**Key words:** ankle fractures, classification, treatment, internal fixation, early motion.

### INTRODUCTION

Ankle fractures are among the most common injuries treated by orthopaedic surgeons. Approximately 2% of the general population will sustain an ankle fracture during their life (1). In Canada approximately 44,000 fractures per year occur about the ankle (66)\_ENREF\_2. Ankle incongruity results in increased contact forces across the tibiotalar joint (56, 48), with the theoretical risk of developing subsequent arthritis and impairment

of function. Epidemiological studies have indicated that 39% of all ankle arthritis is secondary to a previous malleolar fracture (21) and 78% have a post traumatic aetiology (62). Despite the frequency at which this injury is encountered there are still areas where treatment can be optimised. The purpose of this article is to review the current evidence for the treatment of malleolar ankle fractures.

## CLASSIFICATION

The two commonly utilized classifications of ankle fractures are the Lauge-Hansen and Danis-Weber classifications (31, 41, 64). The Lauge-Hansen classification is an experimentally produced system based on cadaveric studies and clinical and radiographic examinations. Four consistent patterns were recognized (foot position at time of injury and applied deforming force): supination-external rotation (SER); supination-adduction (SAD); pronation-abduction (PAB); and pronation-external rotation (PER).

The SER injury pattern is the most common and accounts for 40-75% of all ankle fractures. The order of structures that fail in this injury pattern are: (I) failure of the anterior inferior tibiofibular ligament (AITFL); (II) a spiral oblique fracture of the fibula at the level of the syndesmosis; (III) failure of the posterior inferior tibiofibular ligament (PITFL) or a posterior malleolar fracture; and (IV) tension failure of the deep deltoid ligament or transverse avulsion fracture of the medial malleolus (Fig. 1). Tornetta described a variant of this injury pattern which included a deep deltoid tear and anterior colliculus fracture of the medial malleolus (58).

The SAD injury accounts for approximately 10-20% of ankle fractures and involves (I) a low avulsion fracture of the lateral malleolus or lateral ligament injury; and (II) vertical shear fracture of the medial malleolus (Fig. 2). Impaction of the medial tibial plafond is often associated with this injury.

The PAB injury accounts for 5-20% of ankle fractures and is commonly associated with a syndesmosis injury. The structures that fail are: (I) tension failure of the deep deltoid ligament or transverse avulsion fracture of the medial malleolus; (II) failure of the AITFL and PITFL; and (III) a transverse fibula fracture at or above the level of the syndesmosis typically with lateral comminution secondary to the bending forces applied to the

fibula (Fig. 3). An impaction injury to the lateral tibial plafond can also occur with this injury pattern.

The PER injury accounts for 7-19% of ankle fractures and includes the Maisonneuve injury. The structures that fail are: (I) tension failure of the deep deltoid ligament or transverse avulsion fracture of the medial malleolus; (II) failure of the AITFL; (III) a spiral oblique fracture above the syndesmosis; and (IV) failure of the PITFL or posterior malleolus fracture (Fig. 4). Injury to the syndesmosis often occurs with this injury pattern.

Re-evaluation of the Lauge-Hansen experiments has found that a pure SER mechanism is insufficient to produce the proposed fracture patterns previously reported (35). A subsequent biomechanical study found that they were reliably able to reproduce the Lauge-Hansen SER fracture pattern with the foot in a pronated position (17). Clinical studies have likewise found that the Lauge-Hansen classification has poor predictive abilities with respect to the mechanism of injury and the associated ligamentous injuries. Kwon *et al.* evaluated ankle injury videos from YouTube.com and the corresponding injury films obtained from the individuals sustaining the injuries depicted. In their series the Lauge-Hansen classification was only 58% accurate in predicting the fracture pattern as pertaining to SAD and PER injuries, with it being especially inaccurate in predicting PER injuries (29). A recent study evaluating a series of ankle fractures with MRI found that the Lauge-Hansen classification system had limitations both in its ability to predict the soft-tissue injury as well as in its comprehensiveness (14). Gardner *et al.* found that 53% of the fractures in their series had injury patterns that did not coincide with that predicted by the Lauge-Hansen system and that 17% of the fractures were not classifiable. Due to these limitations, the authors felt the Lauge-Hansen classification should be used as part of the evaluation of an injured ankle and not the sole decision making tool.



Fig. 1. Radiograph illustrating a supination external rotation injury.



Fig. 2. Anterior-posterior radiograph showing a supination adduction type injury. Note the comminution of the medial tibial plafond (arrow).



Fig. 3. Anterior-posterior radiograph showing a pronation adduction injury.



Fig. 4. Radiograph showing pronation external rotation injury with syndesmosis disruption.

The Danis-Weber classification system organizes the fractures based upon the level of the lateral malleolus fracture in relation to the level of the distal tibiofibular syndesmosis (64). Weber type A fractures occur distal to the level of the syndesmosis; Weber type B fractures occur at the level of the syndesmosis (64); and Weber type C fractures occur proximal to the syndesmosis (64). Unfortunately, further clinical experience and biomechanical studies demonstrated that using the level of the fibula fracture to determine the need for and type of surgical treatment was overly simplistic and was often not accurate enough to be truly clinically useful. This classification system does not account for medial sided injuries, which are now considered to be more important determinants for treatment than the level of the fibula fracture. In their analysis of the literature on ankle fractures Michelson *et al.* found that less than 10% of authors found that the Danis-Weber classification system was prognostic or therapeutically predictive (36).

Despite some limitations both systems are widely utilized and can assist in guiding the application of internal fixation.

## TREATMENT OPTIONS

### Weber A

#### *Non-operative*

Fractures of the lateral malleolus below the level of the syndesmosis generally are not associated with ankle stability. As a result these injuries are generally treated without operative intervention. Immobilisation is generally not needed but a walking boot can be used for pain relief if necessary.

#### *Operative*

Operative intervention of this injury pattern is generally dictated by the presence of an associated medial malleolar fracture. Larger lateral malleolar fragments associated with a SAD type injury pattern can be treated operatively. There are multiple fixation options for the fibula, including: hook plate; single screw; or tension band constructs (3).

### Weber B

Lateral malleolar fractures occurring at the level of the ankle syndesmosis are the most common type of ankle fracture and are often SER type injuries. The treatment of these injuries varies depending on numerous factors, which include the presence of an associated medial sided injury as well as syndesmotic integrity. Difficulty can arise when trying to distinguish between an SER type II and SER type IV injury with deep deltoid incompetence and resultant ankle instability.

#### *Non-operative management*

Isolated Weber B fractures without signs of instability (i.e. medial clear space (MCS) <4 mm; difference between superior clear space (SCS) and MCS <1 mm; Tibia/Fibula Overlap >6 mm; Tibia/Fibula Clear Space <6 mm) can be managed non-operatively. Physical examination (medial tenderness, swelling and ecchymosis) has been shown to be a poor predictor of medial sided

injury and associated ankle instability (6, 33). As a result several authors have advocated for the use of an external rotation or gravity stress test (in the absence of radiographic widening of the MCS) to assess medial integrity to better determine which injuries can be safely managed without an operative procedure (33, 37). The gravity stress test is where the lateral aspect of the ankle is positioned towards the floor and a lateral mortise view obtained with the majority of the ankle unsupported off the edge of the table and increased MCS is a sign of deep deltoid incompetence. More recent studies have suggested that the gravity stress test is as reliable as the external rotation stress test and more comfortable for the patient (16, 52).

Ankles that are stable to stress examination are at low risk of subsequent displacement and can be successfully managed non-operatively with an ankle orthosis without weight bearing restrictions (33). Patients with a stress positive radiograph are generally believed to have incompetent deep deltoid ligament and operative management advocated. However, in a small series of stress positive ankle fractures further evaluation with MRI revealed that 90% (19 of 21) had only a partial deltoid disruption and were successfully managed non-operatively in a below knee fracture walker with no weight-bearing restrictions (28). While this study demonstrates that good short-term results can be achieved with non-operative management of stress positive ankle fractures, routine MRI evaluation of ankle fractures would be unsustainable. They suggested that further work is needed to determine the subset of patients that could be managed non-operatively without the need for MRI evaluation.

Hoshino *et al.* evaluated the use of weight-bearing radiographs in this population to ascertain whether this could help delineate which stress positive ankle fractures could be managed non-operatively (23). Patients were initially placed in an unmoulded plaster cast and brought back to clinic 7 days post-injury for re-evaluation. Out of plaster weight-bearing ankle radiographs were then obtained, and if the ankle mortise remained intact (MCS <4 mm or <1 mm difference when compared to the SCS) then the ankles were deemed to be stable and non-operative management was continued. Conclusions from this study were that weight-bearing radiographs performed at an early post-injury clinic visit can help avoid a significant number of operations and that good to excellent early outcomes can be expected using this treatment algorithm.

A recent study performed by the Canadian Orthopaedic Trauma Society investigated non-operative treatment in comparison to operative treatment of unstable lateral malleolus fractures (53). Eighty-one patients with an initially congruent ankle mortise and positive stress radiograph were randomized to non-operative or operative management. Non-operative management consisted of protected weight-bearing in a cast or brace for six weeks. There was no statistically significant difference in the functional outcome between the two groups during the study period. However, there was a loss of reduction

in 8 of 40 patients associated with a MCS measurement greater than 5 mm. The conclusions stated that non-operative management was associated with equivalent functional outcomes in comparison to operative management at one-year follow-up and that older, less active individuals are likely to be safely treated with non-operative treatment. However, given the risk of subsequent misalignment operative intervention should still be considered for younger active patients.

Wei *et al.* reported on a series of patients with bimalleolar and trimalleolar ankle fractures managed with closed reduction and non-operative management (67). Thirty-four patients were managed with 6 weeks of cast immobilization in an above knee, non-weight-bearing cast, which was subsequently converted to a below knee walking cast for an additional 6 weeks. Nineteen of these patients were available for review at an average of 20 years and had excellent AOFAS and Penn Scores. In this small series authors demonstrated that if an anatomic reduction is achieved and maintained, then bi- and trimalleolar ankle fractures can be successfully managed non-operatively; however, the patients need to be carefully selected and requires close follow-up.

#### *Operative Management*

Operative management is suggested for unstable ankle fractures which include: (I) bimalleolar fractures; (II) trimalleolar fractures; (III) lateral malleolar fractures with associated talar shift or talar tilt; and (IV) fracture-dislocations (37). Surgical options include lag screw only fixation; lag screw fixation with supplementation with a lateral neutralization plate; and posterior antiglide plating.

Lag screw only fixation of the lateral malleolus has the potential benefit of requiring less surgical dissection and having less prominent hardware. Tornetta and Creevy investigated the use of lag screw only fixation in 47 ankles meeting specific criteria (59). All of the patients in the series achieved union and there were no soft tissue complications. Only one patient had complaints of residual lateral sided ankle pain and none requested removal of their hardware. The authors concluded that lag screw only treatment of distal fibula fractures is a safe and effective method of fixation in young patients with simple oblique fractures that could accommodate at least two lag screws. A recent retrospective review evaluated 25 consecutive ankle fractures treated with lag screw only fixation in comparison to a cohort matched by age and sex to 25 patients with fractures of similar morphology who had undergone open reduction and internal fixation using lag screw inter-fragmentary compression and a laterally applied neutralization plate (34). The authors found that the lag screw only patients experienced fewer wound complications, less prominent hardware and shorter duration of lateral ankle pain. The authors concluded that lag screw only fixation was superior to plate osteosynthesis in patients with simple oblique or spiral fractures of the lateral malleolus with good bone quality.

Brunner and Weber described posterior antiglide plating of the distal fibula in 1982 (2) (Fig. 5). This tech-

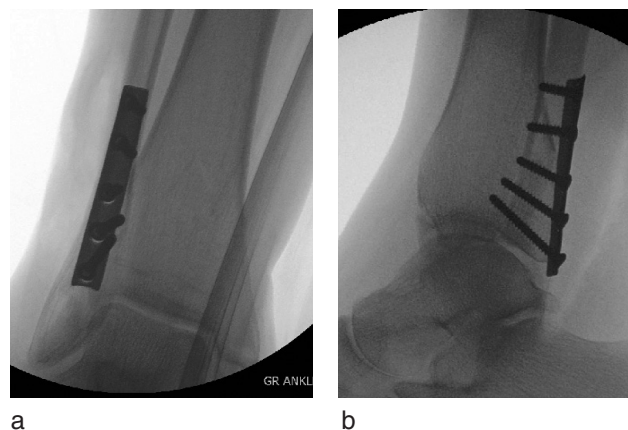


Fig. 5a and 5b. Anterior-posterior (a) and lateral (b) radiograph showing the use of a posterior antiglide plate to stabilize a lateral malleolus fracture.

nique is biomechanically superior to laterally based constructs (40, 50) and proponents of this technique suggest that it requires less surgical dissection; has less hardware prominence; better distal fixation; and avoids the possibility of screw penetration into the ankle joint. This method of fixation is also useful in patients with osteoporosis and poor bone quality. A retrospective review of 193 ankle fractures looking at antiglide fixation in comparison to lateral plate fixation failed to demonstrate a difference a statistical difference between the groups with respect to functional outcome, infection rate, wound dehiscence and hardware removal (30). Weber and Krause found posterior plating of unstable lateral malleolus fractures was associated with high rates of peroneal tendonitis when the most distal screw was placed through the plate in an oblique manner and not fully seated into the plate (65).

The most common method for the fixation of displaced lateral malleolar fractures is lag screw fixation with the addition of a lateral neutralization plate. This is generally done through a lateral incision centered over the fibular fracture. Deep dissection is done to expose the fracture anatomy and the fracture site is carefully cleaned. The fracture is then anatomically reduced and provisionally held with fracture reduction forceps. An inter-fragmentary lag screw is then typically placed anterior to posterior and a one-third tubular neutralization plate is placed laterally using standard technique (Fig. 6).

Syndesmotic injuries can occur with Weber B ankle fractures. Neilson *et al.* demonstrated through their MRI study that syndesmotic injury and interosseous membrane disruption is not associated with the level of the fibular fracture (42). They recommended intraoperative stress testing of the syndesmosis in all operative ankle fractures. Several subsequent studies have confirmed that syndesmotic injuries occur in ankle fractures that biomechanical criteria would not have predicted. Jenkinson *et al.* found that intraoperative fluoroscopic stress examinations increased the rate of detection of unstable syndesmotic injuries (24). The authors found that pre-operative evaluation based on standard radio-

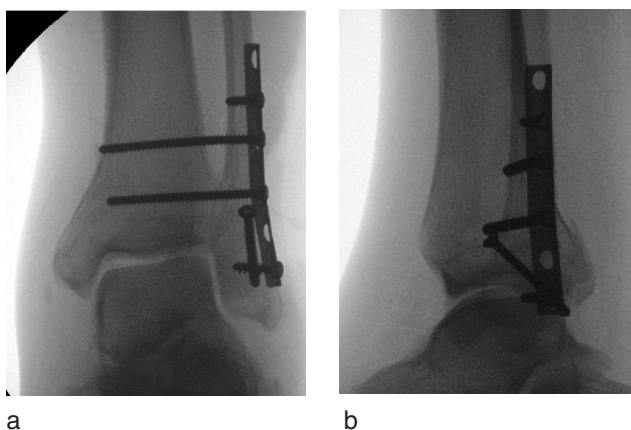


Fig. 6a and 6b. Anterior-posterior (a) and lateral (b) radiograph showing an antero-posterior lag screw and neutralization plate to treat a Weber B fracture with associated disruption of the syndesmosis.

graphy and biomechanical criteria are inadequate by themselves to diagnose syndesmotic injuries. Stark *et al.* specifically looked at syndesmotic instability in Weber B ankle fractures (54). Thirty-nine percent of the Weber B ankle fractures requiring operative stabilization in their series had associated syndesmotic instability after bony stability was restored. A number of other studies have found rates of syndesmotic instability between 17 and 33 percent following malleolar stabilization (18, 24, 46, 66). Ankles that have syndesmotic instability should be stabilized which is generally done with a position screw placed from the fibula into the tibia. The screw is started 2-4 cm from the ankle joint and is directed anteriorly by approximately 30 degrees.

### Weber C and syndesmosis injuries

Restoration of fibula length and rotation is critical in re-establishing a stable ankle and can be radiographically assessed using the talocrural angle (normal range 8-15 degrees). The angle should be within 2-5 degrees compared to the uninjured ankle. If there is significant comminution or poor bone quality this can be restored using indirect reduction techniques. The 'push-pull' technique is a useful adjunct in this situation using a plate fixed distally and a screw positioned outside the plate proximally. An AO laminar spreader can then be used to re-establish length and the plate then fixed to the proximal fragment with length of the fibular restored (Fig. 7).

#### Non-operative

Donken *et al.* reviewed 60 patients with Weber C ankle fractures at an average of 22 years post injury, including 9 patients that were managed conservatively (8). The authors found that conservative management of Weber C ankle fractures can achieve long-term success provided there is no tibiotalar incongruity.

#### Operative

The operative treatment of Weber C ankle fractures involves both restoring the bony anatomy and stabilization of the distal tibiofibular syndesmosis. Weber C frac-



Fig. 7a and 7b. Antero-posterior (a) radiograph showing significant shortening of a Weber C fracture. Fibula length was restored anatomically using a pointed clamp pulling distally to help provide longitudinal traction and in addition, the plate was used indirectly to aid in fracture reduction (b).

tures involving the distal third of the fibula are often treated with plate osteosynthesis. An anatomic reduction of the fibular fracture will aid in the reduction of the distal tibiofibular syndesmosis (19). The forces at the fracture site are unlike those seen with Weber B fractures and short malleable plates are often insufficient to neutralize the forces across the fracture (19). The use of stronger 3.5 mm plates are recommended and at least three screws should be placed proximal to the fracture into the fibular diaphysis (19). Alternatively, stacked one-third tubular plates can be used to make a more robust construct and be less prominent than a 3.5 mm plate (Fig. 8).

The treatment of proximal fibular fractures associated with syndesmotic disruption is generally fixed with



Fig. 8a and 8b. Antero-posterior (a) and lateral (b) radiograph showing the use of two 1/3 tubular plates in order to improve rigidity of a construct but not be as prominent as a 3.5 mm LCDP.

trans-syndesmotic fixation only. It has been recommended that the ankle be held in maximal dorsiflexion while placing syndesmotic fixation to prevent overtightening. In their cadaver study Tornetta *et al.* demonstrated that foot position during the stabilization of the syndesmosis is not related to loss of ankle dorsiflexion (60). Nousiainen *et al.* evaluated the effect of the number of cortices of screw purchase as well as ankle position in a Weber C cadaveric model (43). The authors found that neither the foot position nor the number of cortices of purchase affected the maximal ankle dorsiflexion under axially loaded conditions. There were changes in the syndesmotic width and altered mechanics whether the ankle was fixed in plantarflexion or dorsiflexion.

There is no consensus regarding the optimum treatment modality for injuries to the syndesmosis. Screw fixation is a commonly used method for the stabilization of the distal tibiofibular syndesmosis. The screw is generally placed from the lateral cortex of the fibula into the tibia. Ideally the screws should be directed perpendicular to the tibial incisura to help prevent malreduction. The syndesmosis is reduced and can be held in position with manual pressure or through the placement of temporary K-wire fixation. The use of K-wire stabilization prior to the use of a clamp may aid to prevent antero-posterior translation during reduction of the syndesmosis. The screws are positional and not lag screws. Screws placed through a 2-hole or 3-hole 1/3 tubular plate may help distribute forces of the screw head over a larger surface area (Fig. 9). A recent study demonstrated that clamp placement doesn't reduce the syndesmosis and the authors felt that open reduction of the syndesmosis should be performed to avoid iatrogenic malreduction (38). The angle at which the screws were placed was also evaluated and it was shown that the laterally based screws directed a 0° and posterolateral screws directed at 30° most accurately reduced the syndesmosis.

The size of the screw utilized, the number of screws and the number of cortices engaged are all areas of debate. A prospective, randomized trial comparing quadricortical fixation with a single 4.5 mm screw versus two 3.5 mm tricortical screws demonstrated some benefit to early function with tricortical fixation (22). This difference was not maintained at one year and a follow-up study on the same cohort found no statistically significant differences at an average of 8.4 years post fixation (68).

Screw fixation of the syndesmosis can also be achieved using bioabsorbable implants. Biomechanical studies evaluating bioabsorbable versus stainless steel implants have demonstrated similar mechanical properties (4, 57). Several studies have evaluated the use of bioabsorbable screws for the stabilization of the distal tibiofibular syndesmosis. Thordarson *et al.* compared 17 syndesmotic injuries stabilized with a 4.5 mm polylactic acid (PLA) absorbable screw with 15 stabilized with traditional 4.5 mm stainless steel screws in a randomized study. The two groups had similar complications; radiographic results and range of motion at final follow-up

and the authors concluded that PLA was associated with good short-term results (57). Kaukonen *et al.* also evaluated the use of a bioabsorbable polylevulactic acid (PLLA) syndesmosis screw in patients presenting with an ankle fracture. Forty patients with a clinically verified syndesmotic rupture in association with a malleolar fracture were randomized to syndesmotic stabilization with a 4.5 mm PLLA or a 4.5 mm stainless steel screw. The authors experienced similar results in both groups and concluded that PLLA screw fixation is a reliable and safe method for the stabilization of the syndesmosis (26).

Suture-button fixation of the syndesmosis is a technique that is becoming more common with the introduction of new implants (51). Biomechanical studies on the use on the suture-button technique have demonstrated variable findings. Teramoto *et al.* demonstrated that a standard single suture-button fixation technique could not stabilize the syndesmosis during external rotation force and that the addition of a second device did not change this (55). However, using a suture-button construct that was placed from the posterior surface of the fibula to the anterolateral edge of the tibia and termed the anatomic suture-button fixation, provided physiologic stability to the syndesmosis. Forsythe *et al.* demonstrated that the suture-button construct was unable to maintain reduction of the syndesmosis at any force applied (12). Klitzman *et al.* also assessed the biomechanical stability of suture-button fixation in comparison to screw fixation. They found that suture-button fixation maintained syndesmotic reduction after 1000 cycles of internal and external rotation of the ankle to submaximal loads. The suture-button allowed for significantly more sagittal plane motion than both the intact syndesmosis and the screw fixation (27). Several clinical studies have evaluated suture-button fixation of the syndesmosis. Willmott *et al.* demonstrated in a retrospective analysis of six ankles treated with suture-button fixation a high rate of soft tissue irritation associated with the device. Two of the six cases had problems with soft-tissue irritation and granuloma formation necessitating device removal. In all of the cases, including those with device removal, the syndesmosis remained reduced and patients experienced good clinical outcomes (69). DeGroot *et al.* reported on 24 patients with syndesmotic injuries stabilized with a suture-button technique at



Fig. 9. Radiograph showing syndesmotic fixation using 3.5 mm cortical screws and a 2 hole 1/3 tubular plate acting as a washer.

an average follow-up of 20 months. Patients experienced excellent clinical results with an average AOFAS score of 94 points. However, one in four patients required implant removal due to soft tissue irritation or lack of motion (7). Additionally, there was evidence of osteolysis and implant subsidence in four patients as well three patients with heterotopic ossification.

### Medial malleolus fractures

The medial malleolus is composed of the anterior and posterior colliculi separated by the intercollicular groove. The anterior colliculus is the narrower and most distal portion of the medial malleolus and serves as the origin of the superficial deltoid ligaments. The intercollicular groove and the posterior colliculus, which is broader than the anterior colliculus, provide the origin of the deep deltoid ligaments (45).

#### Non-operative management

Herscovici *et al.* evaluated 57 isolated medial malleolar fractures managed non-operatively (20). Fractures were managed with 6 weeks in non weight-bearing cast immobilization with the foot held in slight inversion with subsequent progression to unrestricted weight-bearing in a fracture walker. Fifty-five of the fractures went on to achieve union with patients experiencing good functional results. Their results suggest that conservative management of isolated medial malleolar fractures is an effective method that is associated with high rates of union. They recommended that fixation of medial malleolar fractures be reserved for bi- and trimalleolar fractures; open fractures; injuries that compromise that skin and those that involve the tibial plafond as well as for symptomatic non-unions.

Posterior collicular fractures begin in the intercollicular groove and extend superiorly and posteriorly. These fractures are difficult to visualize and are rarely displaced due to the tendons of the posterior tibialis and flexor digitorum longus, which stabilize the fracture fragment. Posterior collicular fractures are typically nondisplaced and are treated nonoperatively (10).

#### Operative

Fractures of the medial malleolus are frequently treated operatively. Various techniques have been described for the fixation of medial malleolar fractures including lag screws; tension-band wiring; plates and screws; and bioabsorbable implants. Partially threaded lag screws are a standard and commonly utilized method to treat medial malleolar fractures. Two 4.0 mm partially threaded screws (with washers in softer bone) are utilized to achieve compression across the fracture site. The technique relies on the threads gaining purchase in the cancellous bone of the tibial metaphysis; therefore, screws of approximately 40-45 mm in length are recommended (49). Due to concerns over fixation in the sparse bone of the distal tibial metaphysis, especially in elderly patients, several authors have advocated for the use of bicortical lag screws (47, 49). Fowler *et al.* performed a biomechanical evaluation of various techniques for the fixation of medial malleolar fractures and found that bicortical screw fixation had superior biomechanical

properties to unicortical screws in resisting transverse and tension loads to failure (13). In their combined biomechanical and clinical study Ricci *et al.* found that bicortical screw fixation achieved greater torque generation prior to screw stripping in comparison to 4.0 mm partially threaded screws and was associated with lower rates of screw loosening; symptomatic hardware; and non-union (49).

Tension band fixation of the medial malleolus has been reserved for the stabilization of smaller fragments that are too small for lag screw fixation (44) (Fig. 10). Biomechanical studies have demonstrated that tension band constructs impart superior stiffness in comparison to unicortical lag screws (13, 44). Ostrum had good clinical results with this technique in his clinical series and suggested its use in small, comminuted and/or osteoporotic fractures. The technique involves passing two 2.0 mm K-wires through the distal fragment perpendicular to the fracture plane. The wires are advanced bicortically and then a double loop figure-of-eight construct is fashioned with 18-gauge stainless steel wire. The proximal end on the figure-of-eight wire is passed through a 1.8 mm drill hole created 2-3 cm proximal to the tibiotalar joint. The two loops are then tightened simultaneously to generate symmetrical compression. The use of a heavy absorbable suture can also be used in place of the stainless steel wire, which may be less prominent under the soft tissue envelope decreasing the necessity for future implant removal.

Anterior collicular fractures may occur as an isolated injury or in association with rupture of the deep deltoid ligament and account for 15% to 20% of medial malleolar fractures. If displacement is present on the AP radiograph this indicates that there is an associated disruption of the deep deltoid ligament with resultant instability. Tornetta *et al.* showed that fixation of anterior collicular fractures does not necessarily confer medial stability to the ankle (58). In a series of 27 bimalleolar ankle fractures, the medial malleolus was fixed initially and an external rotation stress view film was taken.

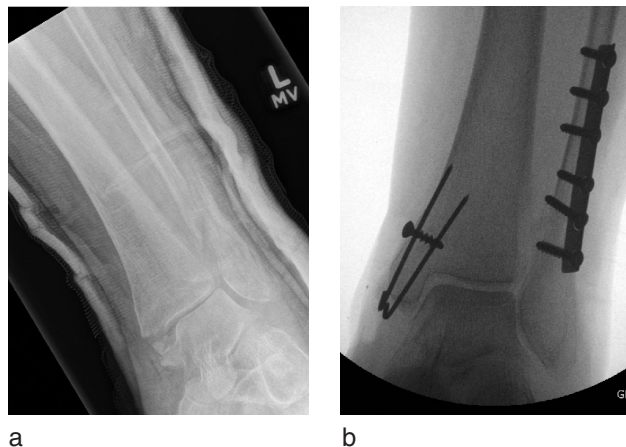


Fig. 10a and 10b. Radiograph showing a small comminuted medial malleolar fracture (a) treated with tension band suture technique (b).

Twenty-five percent of the ankles showed a widened mortise medially. Comparison of fractures with a positive stress test and those without revealed significant differences between medial malleolar height and width. After lateral fixation, all ankles demonstrated a reduced mortise. This study concluded that the size of the medial malleolar fragment was the most important variable in predicting deltoid competence. When the medial malleolus fragment was more than 2.8 cm wide (supracollicular fracture), the deltoid ligament was intact and the stress view was negative. When the fragment was less than 1.7 cm wide (anterior collicular or intercollicular fracture), the deltoid was incompetent and the stress view was positive.

Vertical shear fractures of the medial malleolus require a different strategy due to the vertical orientation of the fracture line. Fixation must be positioned more transversely to prevent secondary shortening and displacement (Fig. 11). A biomechanical study of several methods of fixation for vertical shear medial malleolar fractures found that a neutralization plate with two lag screws placed through the plate offered a significant mechanical advantage over screw only fixations with certain load patterns (9). Several authors recommend the use of an anti-glide combined with lag screw fixation for this fracture morphology (3). The medial tibial plafond also needs to be closely inspected for impaction and if present the joint surface re-established and the defect back-filled with bone substitute and maintenance of reduction with surgical fixation.

### Posterior malleolus fractures

#### Non-operative

Fractures of the posterior malleolus complicate approximately 14 to 44% of all ankle fractures. The indication for surgical stabilization of the posterior malleo-

lus is vague and the overall size of the fracture fragment is often utilized as the main criteria. Non-operative management is generally indicated for fractures involving less than 25% of the joint surface. However, there is little evidence to support this percentage of joint involvement requiring operative intervention. Reduction and stabilization of the fibula often reduces the posterior malleolar fragment though the pull on the posterior tibiofibular ligament (63). Dorsiflexion of the ankle also provides some assistance in the reduction of the posterior malleolar fragment through ligamentotaxis from the posterior capsule.

#### Operative

The size of the posterior malleolar fracture fragment has generally been used as the main indication for surgical intervention. Fractures involving greater than 25% of the tibiotalar joint have generally been treated with operative stabilization. Several authors have suggested that large posterior malleolar fragments should be directly reduced and stabilized (1, 11, 61). Recently Miller *et al.* suggested that all posterior malleolus fractures should undergo open reduction to allow for anatomic reconstruction of the tibial incisura (39). Aside from the overall size of the fracture fragment other factors, including displacement, comminution, syndesmotic injury and joint subluxation, have been reported as possible factors determining treatment of fractures of the posterior malleolus (15). In their survey of over 400 orthopaedic surgeons Gardner *et al.* found high variability regarding surgical treatment of posterior malleolus fractures (15). This variability was evident in both in the indication for operative intervention as well as the in reduction and fixation techniques.

A posterolateral (11, 61) or posteromedial (1) approach to the ankle can be used in order to address a posterior malleolus fracture. Once the fracture is identified



Fig. 11a-c. Radiograph (a) showing a vertical shear medial malleolus fracture which has been treated with a buttress plate with 2 proximal screws (the most distal is at the apex of the fracture) to prevent superior displacement and also a medial malleolus screw. A hook plate has been used both medially and laterally (short end segment of the fibula). Pre and postoperative radiographs (b and c) of a vertical medial malleolus fracture in association with a pronation external rotation type injury.

the fracture fragments are cleaned of callus and interposed soft tissues. Keying in the superior margin of the fracture indirectly reduces the joint and the overall quality of the reduction is assessed by visualizing the medial and lateral borders of the fragment. Fluoroscopy is used to assess the reduction of the joint. Fragments can be provisionally secured using 2.0 mm K-wires. An under contoured antiglide plate can then be applied to the posterior surface of the tibia for definitive fixation of the fracture (Fig. 12). Lag screws can be placed independently or through the plate. Tornetta *et al.* reported on 72 posterior malleolar fractures treated using a posterolateral approach and antiglide plate fixation (61). All of the posterior malleolus fractures healed and there were no incidences of hardware irritation or loosening; however, this approach was associated with a higher rate of non-infected healing complications. A retrospective review of 17 patients treated with a posteromedial approach and buttress plate fixation demonstrated good clinical results. The authors experienced no wound complications and only one case of symptomatic hardware (1).

An alternative method for the fixation of posterior malleolar fractures is the utilization of screw fixation. Reduction of the posterior malleolus is often achieved through the anatomic reduction of the fibula. Application of plate and screw fixation to the lateral malleolus can obscure the articular surface and the posterior malleolar fragment; therefore, provisional fixation with lag screws or K-wires is suggested. The posterior malleolus can then be reduced through the application of a clamp and fixed with screws directed anteriorly to posteriorly.

### Fragility fractures

The incidence of fragility fractures of the ankle secondary to low energy trauma in the elderly is increasing (25). Fragility fractures of the ankle are inherently unstable and in addition poor bone quality and concerns with compromised soft tissue envelope and wound healing makes internal fixation extremely challenging. The-

re is a paucity of literature to guide the optimal treatment for these difficult fractures. Adjuncts which can be used in order to improve fixation are: posterior antiglide plate; bicortical screw fixation distally (possible with posterior antiglide plate) and tri- or quadricortical fixation (use of tibia) proximally for fibula fractures; intra-medullary fixation of fibula; use of intra-medullary fibula K-wires in addition to plate fixation to improve screw purchase; locking plate fixation; the use of bone substitutes/cement augmentation; and tension band fixation of medial malleolus fractures. Interestingly biomechanical comparison between an antiglide plate and distal fibula locking plate showed that the antiglide construct was superior (40). An alternative stabilisation method is the use of calcaneotibial nail stabilisation which has been shown to be successful in this difficult group of patients (32).

### CURRENT AREAS OF TREATMENT UNCERTAINTY

1. The optimal test to distinguish between stable (SER II) and unstable (SER IV) injuries is still an area of controversy. Even if stress tests are positive successful non-operative management has been reported. The exact subsets of patients which need surgical intervention and those that don't still needs to be clarified. Further work is necessary in order to further delineate these injury patterns in order that appropriate treatment provided.
2. Ongoing debate regarding the optimal technique for treating syndesmosis injuries (open or closed reduction) and fixation method still exists. It is imperative that anatomical reduction of the syndesmosis is necessary and that closed reduction techniques can result in malreduction.
3. Medial malleolus fractures are very variable in morphology and often too small for double screw fixation and the question whether a single screw is sufficient is currently being investigated.



a | b

Fig. 12a and 12b. Antero-posterior (a) and lateral (b) radiograph showing the use of an under-contoured plate with lag screw used to buttress a large posterior malleolus fracture.

4. Posterior malleolus fractures vary in size and at present there is no Level I/II evidence to support what size of fragment requires fixation?
5. Fragility fractures in osteoporotic bone are a challenge and the incidence steadily rising. More research is necessary to determine the optimal fixation.

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