Ankle fractures are among the most common skeletal injuries that require orthopedic care, representing 9% of all fractures. A threefold increase in these injuries was documented in the Finnish population between 1970 and 2000. The incidence of ankle fractures is expected to continue to increase, especially in those older than 65 years.

Mechanism of Injury
Malleolar fractures most often are caused by low-energy rotational injuries. There is a bimodal age distribution between young, active individuals and the elderly with poor bone quality, and the incidence is increasing among older women.

Anatomy
The ankle joint is a saddle-shaped articulation among the talus, distal tibia, and fibula. Stability of the ankle relies on the integrity of the medial and lateral osseoligamentous complexes as well as the distal tibiofibular syndesmosis.

The medial malleolar osseoligamentous complex comprises the medial malleolus and the superficial and deep deltoid ligaments. The superficial deltoid ligament functions primarily to resist eversion of the hind foot, whereas the deep deltoid, which is oriented more transversely, limits external rotation of the talus. The superficial deltoid originates from the anterior colliculus of the medial malleolus, and the deep deltoid originates from the larger and more distal posterior colliculus. An understanding of this anatomy is critical because an isolated injury of the anterior...
The chondral injury has been seen in a buttress against lateral translation of the talus. This is believed to be secondary to the stabilizing effect of the deep deltoid ligament, which primarily prevents external rotation of the talus during plantarflexion. Lateral ligamentous stability is afforded by the anterior talofibular, calcaneofibular, and posterior talofibular ligaments, progressively limiting inversion and adduction of the ankle joint.

The inherent tibiotalar congruity up to 100% by forcing the talus rotates internally and is stabilized and guided medially by the deltoid ligament. Ankle joint instability as a result of compromised anatomy results in altered physiologic motion of the talus, leads to decreased articular congruity and increased contact pressure, and theoretically increases the risk of degenerative joint disease. However, biomechanical studies evaluating the relative contributions of the medial and lateral components have shown conflicting results. In an index cadaveric study, Ramsey and Hamilton found that a 1-mm lateral talar shift decreased contact area by 42%. Other studies did not replicate this dramatic finding, but the observed “lateral translation” of the talus has been challenged. Computed tomography showed that the anatomic relationship between the distal fibula and the talus is unchanged. Instead, the increased medial clear space has been determined to be the result of internal rotation of the proximal fibula and anterolateral rotation of the talus, which had no effect on ankle stability. In a cadaveric model, in the setting of transverse osteotomy of the distal fibula, up to 6 mm fibular displacement resulted in a significant finding of no change in tibiotalar contact area; however, sectioning of the deltoid created a 15% to 20% decrease in contact area; however, sectioning of the deltoid created a 15% to 20% decrease in contact area. Conversely, in medial malleolus nonunion or complete absence of the medial malleolus, instability was not reported. Therefore, perhaps the bony constraint provided by the medial malleolus has been overemphasized.

Despite anatomic reduction and restoration of normal kinematics, posttraumatic degenerative joint disease has been observed in 14% to 50% of ankle fractures. Chondral injury has been seen in 79% to 90% of these injuries and is a significant independent predictor of ankle posttraumatic osteoarthritis. Therefore, although decreased tibiotalar contact area may lead to increased risk of posttraumatic degenerative joint disease, the true etiology, either cartilage injury at the time of trauma or increased contact pressure over time, remains to be determined. However, static evaluation of displacement may provide an inadequate indirect assessment of altered biomechanics of the ankle.

BIOMECHANICS

Although it is often oversimplified as resembling a simple hinge, the motion of the ankle joint is a complex combination of sliding and rolling. The ankle typically bears up to 4 times the body weight under physiologic conditions. With the ankle in neutral position, nearly 80% to 90% of the weight is borne through the tibiotalar articulation, and the remainder is borne through the medial and lateral malleolar articulations. The medial articulation contributes minimally with the ankle in the neutral position, but it contributes up to 22% with varus and valgus stress.

Loading of the ankle increases joint congruity up to 100% by forcing the talus to seat concentrically beneath the tibial plafond. The inherent tibiotalar congruity is chiefly responsible for this conformity. The talus is trapezoidal, with greater width anteriorly, providing a highly congruent fit with the ankle in dorsiflexion. However, when the uninjured ankle is brought into plantarflexion, the talus is brought into plantarflexion, the talus rotates internally and is stabilized and guided medially by the deltoid ligament. 

The ankle typically is brought into plantarflexion, the ankle is brought into plantarflexion, the ankle in dorsiflexion. This highly congruent fit with the ankle in dorsiflexion. However, when the uninjured ankle is brought into plantarflexion, the talus is brought into plantarflexion, the talus rotates internally and is stabilized and guided medially by the deltoid ligament. 

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CLINICAL AND RADIOGRAPHIC EVALUATION

History and physical examination are instrumental in determining the management strategy for malleolar fractures. Patient physiologic age, comorbidities, level of physical demand, and preference are often essential factors in surgical decision making. Nonoperative management is reserved for patients with low functional demand and those who are unable to undergo surgery. Uncontrolled diabetes, peripheral vascular disease, and peripheral neuropathy are associated with significantly greater risk of complications after both operative and nonoperative management. Strong fixation and increased immobilization are needed in this patient cohort. The mechanism of injury can further aid in determining the location and extent of injury.

Gross deformity, ecchymosis, or significant tenderness over the malleoli signifies injury. Assessment of soft tissues helps to determine the timing of surgery. Significant swelling, fracture blisters, and open or impending open injuries necessitate delaying or staging surgery. The proximal fibula always should be examined in the setting of an isolated medial malleolar injury to exclude Maisonneuve fracture.

Standard 3-view radiographs of the ankle should be obtained to assess displacement and collricular involvement. The lateral ankle view should be evaluated to determine the size of the medial malleolar fragment, if present, because this can be a clue to the possibility of bony and ligamentous injury and the associated operative implications. In a patient with isolated lateral malleolar fracture with no talus tilt or syndesmotic or medial clear space widening on static films, either gravity or
The first word in
the classification describes the position of
the foot at the time of injury, and the sec-
ond word describes the direction of force,
with increasing severity depending on the
degree of injury. The original description
was intended to guide closed manage-
ment of ankle fractures, based on a bet-
ter understanding of the mechanism of
injury, to aid in reduction by reversing the
mechanism of injury. However, this clas-
sification system is complex, with poor
interobserver and intraobserver reliability
and limited prognostic value.5
Alternatively, the Weber/OTA clas-
sification, described in 1966, is anatomi-
cally based and depends on the location of
fibular fracture with respect to syndesmo-
sis.28,29 This classification is based chiefly
on the lateral malleolus as the perceived
primary stabilizer and does not account
for medial instability. Although it is sim-
ple and easy to use, this classification sys-
tem creates heterogeneous groups of frac-
tures (Weber B) with otherwise distinct
biomechanical characteristics and does
not account for medial malleolar involve-
ment. Efforts to account for both medial-
and lateral-sided injuries have resulted in
complex classification systems similar to
the Lauge-Hansen classification. Integra-
tion based on combining multiple mecha-
nisms has been proposed.30
Medial Malleolar Classification Systems
There have been additional attempts
at medial malleolar fracture classification
systems based on fracture geometry.18,26
Herscovici et al18 evaluated the outcomes
of 57 isolated medial malleolar fractures
and divided them into 4 simple patterns
(A-D) based on fracture location and
obliquity. Type C fractures, located at the
level of the plafond, were most common,
and 93% had uneventful union with non-
operative management.
Ebraheim et al26 divided 112 me-
dial malleolar fractures into transverse,
oblique, vertical, and comminuted types
and correlated both the mechanism of in-
jury and syndesmotic integrity with the
observed fracture pattern. These authors
found that transverse fractures were the
most common and correlated with supi-
nation-external rotation injuries (r=0.34),
oblique fractures with pronation-external
rotation (r=0.35), and vertical fractures
with supination-adduction (r=0.87). Fur-
ther, transverse fractures were most of-
ten correlated with syndesmotic injury
(r=0.20). In addition, 64% of transverse
medial malleolus fractures and 52% and
29% of oblique and vertical fracture pat-
terns, respectively, had syndesmotic dis-
ruption (Figure 1). Assessment of the me-
dial malleolar fragment, although possibly
not as important as previously believed, is
still necessary. Both syndesmotic injury
and deltoid injury can be suspected from
the geometry, allowing appropriate surgi-
cal planning.
The ideal classification system would
include consideration of all components
of the joint, with high intra- and interob-
servers reliability and the ability to guide
surgical decision making.31 A more com-
prehensive medial malleolar fracture clas-

Figure 1: Anteroposterior view of a transverse injury, associated with syndesmotic injury in 64% of cases (A). Anteroposterior view of an oblique injury, associated with syndesmotic injury in 52% of cases (B). Anteroposterior view of a vertical injury, associated with syndesmotic injury in 29% of cases (C).

The first word in the classification describes the position of the foot at the time of injury, and the second word describes the direction of force, with increasing severity depending on the degree of injury. The original description was intended to guide closed management of ankle fractures, based on a better understanding of the mechanism of injury, to aid in reduction by reversing the mechanism of injury. However, this classification system is complex, with poor interobserver and intraobserver reliability and limited prognostic value. Additionally, medial malleolar fracture geometry has been shown to be predictive of the mechanism of injury as well as the integrity of the syndesmosis. A retrospective review of 112 ankle fractures found that transverse medial malleolar fractures were associated with syndesmotic injury in 64% of cases and therefore should be addressed.

Computed tomography also may aid in the evaluation of isolated anterior vs supracollicular medial malleolar fractures and thereby guide decision making based on the perceived contribution of the fragment to joint stability. A larger medial malleolar fragment is more likely to be attached to a competent deltoid ligament.

Modern Classification Systems and Shortcomings
Classification Systems
The 2 most prevalent classification systems are the Lauge-Hansen and Weber/OTA systems. However, both systems have a limited ability to predict the prognosis or guide the management of medial-sided injuries. The Lauge-Hansen classification is based on the mechanism of injury and was first described in 1950.27 The first word in
Historical Perspective on the Management of Ankle Fractures

The history of operative management of malleolar fractures is characterized by a tug-of-war between proponents of either the medial or lateral malleoli acting as primary stabilizers of the ankle joint.

In 1945, Muller established the importance of the medial malleolus in restoring articular congruity and joint stability. In a small series of 20 ankle fractures, including 13 isolated medial malleolar fractures, the authors noted that reduction of the medial malleolus would be followed by reduction of the talus and fibula. From 1930 to the 1960s, most ankle fractures were treated nonoperatively. However, if managed surgically, the medial malleolus was often fixed and the lateral malleolus was treated closed because it was believed that the medial malleolus was key to restoring talar stability. Results obtained while operating under this premise were unsatisfactory and similar to those obtained with nonoperative management.

Since the mid-1970s, there has been an increasing tendency toward operative fixation of more severe ankle fractures. Yablon et al first challenged this assertion, given the author’s observation that the talus and subsequently the medial malleolus “faithfully” followed reduction of the fibular component. Over the next 40 years, the emphasis returned to anatomic reduction of the lateral malleolus. Pettrone et al established the first objective criteria for operative intervention, concluding that the order of importance for restoration of stability was the lateral malleolus, medial malleolus, deltoid ligament, and syndesmosis. If these restraints are compromised and the ankle joint is unstable, open anatomic reduction with internal fixation is advocated to restore native biomechanics. More recent research has upheld the idea that the medial structures act as the primary stabilizers under physiologic conditions. Disruption of either the ligamentous or osseous stabilizers of the medial articulation alters the stabilizing effect on the talus and leads to significantly altered joint biomechanics, including external rather than internal rotation of the normally highly congruent talus. With intact medial elements, disruption of the lateral structures does not result in abnormal station or motion of the talus. Further, a nonanatomically stationed talus is evidence of disruption of the medial structures. Therefore, if the talus is anatomically reduced in the setting of a non-displaced or minimally displaced medial malleolar fracture, relative function may be intact and operative intervention may be unnecessary. Perceived displacement and external rotation of the distal fibula are indirect evaluations of medial-sided incompetence. The talus and distal fibula rotate externally, increasing the medial clear space, whereas the talofibular relationship remains intact.

Management of Medial Malleolar Fractures

Goals of Management

The ultimate goal of the management of medial malleolar fractures, either in isolation or in the setting or bi- or trimalleolar injuries, is to avoid symptomatic nonunion or malunion, dynamic ankle instability, static articular incongruity, and posttraumatic osteoarthritis.

Indications for Nonoperative Management

Contemporary nonoperative management is generally recommended for isolated fractures that are nondisplaced or minimally displaced (≤2 mm), for avulsion injuries, for staging surgery as a result of compromised soft tissues, and for cases where medical comorbidities or patient preferences exclude operative intervention. However, the literature has not consistently shown the superiority of operative management over nonoperative management. However, for nonunion or malunion, the decreased contact area and increased contact pressures have been found to be significant.

Further, there is a significant degree of variation in practice among orthopedic surgeons for operative management of ankle fractures. In a recent survey, only 82% routinely chose surgery for grossly unstable type IV supination external rotation ankle fractures.

Controversy Over Operative Versus Nonoperative Management

Few studies have compared outcomes after nonoperative and operative management of both isolated medial malleolar fractures and medial malleolar fractures in the setting of bi- and trimalleolar fractures.

Isolated Medial Malleolar Fractures

Only 1 study specifically evaluated outcomes after conservative management of medial malleolar fractures. This study excluded bi- or trimalleolar patterns, instability noted by talar subluxation or shift, and skin lesions precluding closed treatment. The authors stratified injuries based on fracture configuration and found excellent rates of union (96%) and functional results for 57 isolated medial malleolar fractures treated conservatively at a minimum 2-year follow-up. Despite the varying obliquity of the fractures, no medial instability, mortise incongruity, or radiologic displacement occurred. The authors recommended operative fixation for bi- and trimalleolar ankle fractures. However, the study was noncomparative and included only short-term outcomes.

Bi- and Trimalleolar Ankle Fractures

Support for operative vs nonoperative management of medial malleolar fractures in the setting of bi- or trimalleolar fractures is mixed. Operative management is favored, but some studies found...
no difference in clinical or radiographic outcomes.\textsuperscript{41,51} Tornetta\textsuperscript{6} retrospectively reviewed a series of 27 bimalleolar ankle fractures and found that the size of the medial malleolar fragment was the most significant predictor of deltoid competence. This study found that the deltoid ligament was incompetent and the ankle was unstable on external rotation stress radiographs after fixation of all medial malleolar fractures less than 1.7 cm wide on lateral radiograph.\textsuperscript{6} The instability in this fracture pattern was attributed to concomitant bony injury of the anterior colliculus and ligamentous injury of the deep deltoid (\textbf{Figure 2}). Although fixation of the medial malleolus did not restore ankle stability, fixation of the lateral malleolus was accurate and the joint space was maintained. These findings suggest that primary repair is not necessary and sometimes provides a suboptimal outcome. However, a large fragment (>2.7 cm) may be considered for fixation because it restores an intact deltoid (\textbf{Figure 2}).\textsuperscript{6}

\textbf{Figure 2:} Anteroposterior (A) and lateral (B) views of an anterior colliculus fracture with concomitant deltoid injury. Isolated bony fixation of the fragment does not provide medial stability. However, concomitant fixation of the fibula restores stability to the mortise without the need for deltoid repair. Anteroposterior (C) and lateral (D) views of a large medial malleolus fragment with an intact deltoid attached. Isolated bony fixation provides medial stability.

Only 1 study specifically compared operative vs nonoperative management of medial malleolar fractures for more complex ankle fractures. Nonoperative management of minimally displaced medial malleolar fractures after operative fixation of the fibula showed intermediate-term results comparable to those of operative fixation in unstable bi- and trimalleolar fractures.\textsuperscript{41} In this study, patients were randomized to either operative or nonoperative fixation of the medial malleolus, with 37 and 45 patients in each group, respectively. At median follow-up of 39 months, no functional or radiographic differences were found between the groups. Although 4 patients had nonunion of the medial malleolus with fracture gap greater than 2 mm, these patients had no functional disabilities, and their functional scores were above average. The true clinical significance of these asymptomatic nonunions was undetermined. Therefore, the authors recommend nonoperative management only when soft tissues or patient characteristics do not permit fixation.

At 20-year follow-up of bi- and trimalleolar ankle fractures, Wei et al\textsuperscript{51} found that anatomic reduction was maintained, with outcomes comparable to those with operative fixation but without the risks of surgery. Of 19 patients who were available for review at 20-year follow-up, only 2 had mild symptoms or degenerative changes on radiography. With a quoted deep infection rate of 5% and a 10% incidence of loss of reduction with surgical management, the authors suggest reconsidering a universal recommendation for surgical management of these injuries.

\textbf{Conclusion}  
The biomechanical and clinical literature on the necessity of medial malleolar fracture fixation is sparse and inconclusive. Anatomic studies have reported conflicting results, showing both the medial and lateral structures to be primary stabilizers. Further, few clinical studies have shown that isolated medial-sided fixation
may lead to worse clinical results in bimalleolar ankle fractures and that isolated lateral-sided fixation may be as effective as dual-sided fixation and actually may provide superior clinical benefit. Therefore, it is difficult to say that the medial side is the most important determinant of ankle stability.

Prospective comparative studies evaluating fixation vs conservative management of medial malleolar fractures are needed. Additionally, studies are needed to evaluate the effect of fracture geometry (vertical shoulder fracture vs avulsion of the tip), residual displacement after reduction of the fibular fracture (whether the medial malleolus reduces), and long-term patient-centered outcomes (symptomatic nonunion, malunion, and posttraumatic osteoarthrosis).

Because there is no consensus in the literature, the authors recommend nonoperative management for patients with specific injury characteristics, including compromised soft tissue coverage on the medial side and expected increased likelihood of complications (uncontrolled diabetes, advanced renal disease). Conversely, operative fixation is warranted in young, high-demand, otherwise healthy patients who have supracollicular fractures with unacceptable station of the talus or residual displacement of the medial malleolar fragment after fixation of the fibula and syndesmosis.

**References**

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