# Deltoid Ligament Integrity in Lateral Malleolar Fractures: A Comparative Analysis of Arthroscopic and Radiographic Assessments

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*Foot and ankle surgeons often rely on the medial clear space to evaluate competency of the deep deltoid ligament when evaluating ankle fractures. This investigation assesses the integrity of the deep deltoid ligament after lateral malleolar fracture by using direct arthroscopic visualization and medial clear-space separation on plain film radiographs. The objectives of this study were to test the reliability of medial clear-space separation and the Lauge-Hansen classification scheme in predicting deep deltoid rupture in displaced lateral malleolar fractures. The medial clear space was measured on injury radiographs of 40 patients with an isolated displaced lateral malleolar fracture who underwent open reduction and internal fixation. Injury radiographs were classified according to the Lauge-Hansen scheme. Direct arthroscopic visualization was used to evaluate the deep deltoid ligament under manual stress before fracture reduction. The mean preoperative medial clear space in patients with a deep deltoid rupture (n = 13) was 6.6 ± 2.4 mm (range, 4 to 12 mm), and in patients without a deep deltoid rupture (n = 26), it was 4.0 ± 1.0 mm (range, 2.5 to 6 mm) (*P *= .002, 2-sample t test). At an injury medial clear space ≥3 mm, the false positive rate for deltoid rupture was 88.5% (*P *= .54, Fisher's exact test). At ≥4 mm, the false positive rate was 53.6% (*P *= .007). All fractures were rotational injuries according to the Lauge-Hansen system. Three fractures were not classifiable; another 3 fractures showed deltoid ligament integrity opposite the expected finding. The results indicate that, in isolated displaced fractures of the lateral malleolus, radiographic widening of the medial clear space is not a reliable indicator for deep deltoid rupture. Some fractures considered stable by the Lauge-Hansen classification may require careful scrutiny to rule out deep deltoid injury.* (The Journal of Foot & Ankle Surgery 43(1):20–29, 2004)

Key words: deltoid ligament, ankle fracture, ankle arthroscopy, talar shift medial clear space

The criterion for surgical treatment of displaced lateral malleolar ankle fractures remains controversial despite cadaver investigations and clinical outcome studies that have advanced our understanding of the pathologic anatomy and prognostic determinants of such fractures (1–23). If medial ankle tenderness is elicited on clinical examination, coupled with significant lateral talar shift on standard radiographs, a deep deltoid ligament rupture is presumed. Surgical reduction of the lateral malleolus is indicated to restore the ankle mortise (1–4). However, in displaced lateral malleolar fractures with medial ankle tenderness in which lateral talar shift is less marked or even absent altogether, the onus for surgical treatment is less convincing given the favorable long-term outcomes of nonsurgical treatment for isolated lateral malleolar fractures (5–7). Reliable radiographic determination of deltoid ligament rupture in such uncertain cases has not been possible in the clinical setting.

Radiography has long been used to infer ligament disruption in ankle fracture dislocation injuries. Staples (8) in 1960 referred to the deltoid rupture as the "invisible injury" and observed that it could be easily missed on standard ankle radiographs. Widening of the medial clear space

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1067-2516/04/4301-0005$30.00/0
doi:10.1053/j.jfas.2003.11.005

(MCS) between the talus and the medial malleolus is the classic radiographic finding for deltoid ligament rupture (8–15), substantiated by more recent cadaver and clinical investigations (16–21). These studies constitute the evidence for lateral talar shift with and without deltoid ligament constraint in the setting of a lateral malleolar fracture. There is no literature that directly correlates deltoid ligament integrity in displaced lateral malleolar fractures in vivo with corresponding MCS measurements on standard ankle injury radiographs. This association could influence decision making for the surgical treatment of lateral malleolar fractures with clinical suspicion of deltoid ligament rupture despite indefinite radiographic findings.

The seminal work of Lauge-Hansen (22–25) on ankle injury mechanisms, radiographic classification, and closed reduction technique has become one of the most widely used classification schemes in clinical practice. The system is designed to guide fracture reduction and treatment based on radiographic injury evaluation (26). Associated ligamentous injuries may be diagnosed based on sequential injury patterns, the end result of which should be an accurate determination of ankle fracture stability (25, 27). Central to this process is the assessment of deltoid ligament integrity in the presence of a displaced lateral malleolar fracture. Biomechanical studies of the axially loaded ankle suggest that medial injury determines stability in ankle fractures (1, 28–34). If the Lauge-Hansen classification scheme has clinical usefulness for the treatment of displaced lateral malleolar fractures, it should be a reliable predictor of deltoid ligament ruptures.

Nonanatomic treatment of a minimally displaced lateral malleolar fracture guided by radiographic signs may result in poor outcomes and may increase patient morbidity. The primary aim of this study was to determine the capacity of the MCS on injury radiographs in assessing the integrity of the deep deltoid ligament in the displaced lateral malleolar fracture. A secondary objective was to evaluate the accuracy of the Lauge-Hansen classification system as a predictor of deltoid ligament integrity in displaced fractures of the lateral malleolus. This retrospective clinical study correlates injury radiograph MCS measurements with arthroscopically assessed deltoid ligament integrity in displaced lateral malleolar ankle fractures.

## Materials and Methods

Between April 1997 and March 2001, patients admitted to the Kaiser Permanente Medical Center in San Francisco, CA, who sustained a displaced lateral malleolar ankle fracture and were treated with open reduction and internal fixation were selected for evaluation. Patients with fractures of the medial malleolus were excluded. Fifty-six patients who met these inclusion criteria underwent arthroscopic evaluation of the deep deltoid ligament during the surgical procedure to repair the fracture. The deep deltoid ligament was defined by the deep posterior tibiotalar ligament, established as a primary and consistent intraarticular component of the deep deltoid, according to a number of anatomic studies (35–40). In all patients, after standard exposure of the distal aspect of the fibula, a 4.0-mm, 70° arthroscope was inserted superiorly into the lateral ankle joint through the corridor created by the anterior joint capsule, and inferiorly into the dorsal aspect of the talar dome. The deltoid was inspected visually and photographs were taken with the foot both internally and externally rotated while the midtibial shaft was stabilized. The deltoid ligament complex was manually stressed intraoperatively by applying external rotation forces to the foot. In some instances, visualization was aided by the creation of an anteromedial arthroscopic portal. The integrity of the deep deltoid ligament was classified as intact, partially ruptured, or completely ruptured, and recorded as part of the surgical record. The lateral malleolar fracture, and syndesmosis disruption when appreciated, was repaired by standard AO technique with a plate, screws, and Kirschner wires as necessary. Arthroscopic ligament assessment and deltoid stress maneuvers were performed by 1 surgeon (J.M.S.).

Complete medical records and radiographs of 40 patients (26 men and 14 women) with a mean age of 43.5 years (range, 16 to 77 years) were accessible for study. Surgical reports were reviewed to confirm the absence of a medial malleolar fracture, arthroscopic findings, and the method of internal fixation. Nonweightbearing radiographs of the injured ankle taken before closed reduction and/or splint immobilization included anteroposterior, mortise, lateral, and proximal fibular views, when indicated. These were compared with postoperative radiographs with 3 standard projections. The MCS was measured on the mortise view of all pre- and postoperative nonweightbearing radiographs. The mortise radiograph has been shown to permit the most exact evaluation of mortise widening (17, 41). The MCS was determined by a line drawn from medial shoulder of the talus extending inferiorly along the medial cortex to the most inferior margin of the medial talar facet. At its midpoint, second line was drawn perpendicular to the medial malleolus. The distance between the most medial aspect of the talus and the most lateral aspect of the medial malleolus was measured along this perpendicular line and recorded. This distance was determined to be the MCS (Fig. 1). Each MCS was measured 3 times, and the average was determined to the nearest half-millimeter. All measurements were performed over a period of several weeks by the resident author (D.R.C.), using the same method.

Injury radiographs were categorized according to the Lauge-Hansen classification scheme (22) by the senior author who was initially blinded to the corresponding arthroscopic pictures. In cases in which the MCS was widened

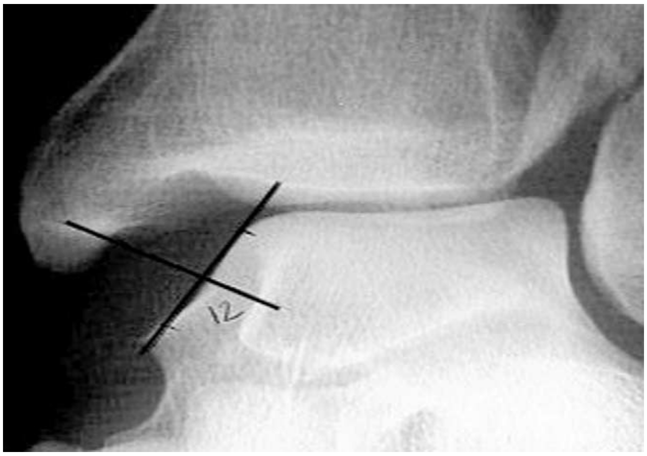

**FIGURE 1** Method for measurement of the MCS.

beyond 3 mm or greater than the superior joint space of the ankle mortise, deltoid rupture was presumed. Any radiograph fracture pattern that did not fit the Lauge-Hansen scheme was deemed unclassifiable.

Data analysis included the MCS mean, range, and standard deviation for patients with intact and ruptured deep deltoid ligaments. A 2-sample *t* test was used to determine differences between MCS measurements in patients with an intact deltoid compared with those who sustained a deltoid rupture. A Fisher's exact test was used to establish at what MCS value the difference between an intact and ruptured deltoid was significant. The level of significance was set at $P < .05$.

## Results

All study data is listed in Table 1. The average period between ankle fracture and surgical repair was 2.1 days (range, 0 to 14 days). All fractures were rotational injuries. There were 22 supination external rotation (SER) II injuries, 1 SER-III injury, 7 SER-IV injuries, 2 pronation external rotation (PER) III/IV injuries, and 5 PER-IV injuries. Three fractures were not classifiable according to the Lauge-Hansen scheme. There were 26 intact deep deltoid ligaments, 13 complete ruptures, and 1 partial rupture. The case with the partial deltoid rupture was not considered for data analysis. Table 2 compares the Lauge-Hansen fracture patterns determined by radiographs with deep deltoid ligament integrity determined by arthroscopy.

For all ankle fractures, the mean preoperative MCS was 4.9 ± 2.0 mm (range, 2.5 to 12 mm); the mean postoperative MCS was 2.8 ± 0.8 mm (range, 1.5 to 6 mm). In the group with a deltoid rupture (n = 13), the mean preoperative MCS was 6.6 ± 2.4 mm (range, 4 to 12 mm); in the group with an intact deltoid (n = 26), the mean preoperative MCS was 4.0 ± 1.0 mm (range, 2.5 to 6 mm). A 2-sample *t* test showed a significant difference in the mean preoperative MCS between the 2 groups ($P = .002$). The mean postoperative MCS in the group with deltoid rupture was 3.5 ± 2.1 mm (range, 2 to 6 mm). In the group with an intact deltoid, the mean postoperative MCS was 2.7 ± 1.0 mm (range, 1.5 to 3.5 mm). The pre- to postoperative MCS reduction in the group with a deltoid rupture was significantly larger ($P = .0003$). The minimum MCS at which a deltoid rupture occurred was 4 mm. The maximum MCS at which the deltoid remained intact was 6 mm. Table 3 lists all MCS measurements and correlates them with the number of intact and ruptured deltoid ligaments.

A MCS value of ≥2 mm did not predict deltoid integrity, because the MCS on injury radiographs was ≥2 mm for all patients. Notable differences between the patient group with an intact deltoid and the group with a ruptured deltoid were found with MCS measurements in the range of ≥3 to 6 mm. The preoperative MCS was ≥3 mm in all patients with a deltoid rupture (n = 13). In the group with an intact deltoid, 88.5% (n = 23) had a preoperative MCS ≥3 mm. However, this difference was not statistically significant ($P = .54$) using Fisher's exact test. At an MCS ≥3 mm, the false positive rate for deltoid rupture was 88.5%.

The preoperative MCS was ≥4 mm in all patients with a deltoid rupture, whereas 53.6% (n = 15) of patients with an intact deltoid had a preoperative MCS ≥4 mm. This difference reached statistical significance ($P = .007$), using Fisher's exact test. At an MCS ≥4 mm, the false positive rate for deltoid rupture was 53.6%. In the group of patients with a deltoid rupture, 69.2% (n = 9) had a preoperative MCS measuring ≥5 mm; 26.9% (n = 7) of patients with an intact deltoid had a MCS ≥5 mm. This difference was significant ($P = .017$). At this MCS, the false positive rate for deltoid rupture diminished to 26.9%. Finally, 61.5% (n = 8) of patients with a deltoid rupture had a MCS measuring ≥6 mm, but this MCS measurement was present in only 2 patients with an intact deltoid, which was a significant difference ($P = .0007$). At this MCS measurement, the false positive rate for deltoid rupture was only 7.7%.

## Discussion

Cadaver experiments of deltoid ligament mechanics show that the deep deltoid ligament limits external rotation of the talus particularly in plantarflexion (1, 30, 34, 42, 43). It also restricts lateral shift and anterior displacement of the talus (11, 18, 44). The deep posterior tibiotalar component provides significant resistance to lateral and posterior talar shift, as well as ankle dorsiflexion (40). The deltoid complex is most vulnerable to loading injury when the talus is externally rotated, everted, and plantarflexed (45). In ankle injury, the talus becomes unstable in the ankle mortise in the direction of anterolateral rotation (28, 30, 43, 46, 47).

**TABLE 1 Patient data**

| Patient Age (yr) | Lauge-Hansen Classification | Deltoid Integrity | Injury MCS (mm) | Postoperative MCS (mm) | Hardware |
|---|---|---|---|---|---|
| 24 | SER II | Intact | 2.5 | 3.5 | 5 hole/1 IF |
| 67 | SER III | Intact | 2.5 | 2 | 7 hole/1 IF/K-wire |
| 48 | SER II | Intact | 2.5 | 2.5 | 6 hole/1 IF |
| 33 | SER II | Intact | 3 | 2 | 5 hole/1 IF |
| 42 | SER II | Intact | 3 | 2 | 5 hole/1 IF |
| 70 | SER II | Intact | 3 | 2 | 5 hole/1 IF |
| 36 | SER II | Intact | 3 | 3 | 7 hole/1 IF |
| 33 | SER II | Intact | 3.5 | 2 | 6 hole/1 IF/K-wire |
| 58 | SER II | Intact | 3.5 | 2.5 | 5 hole/1 IF |
| 27 | SER II | Intact | 3.5 | 3 | 1 IF |
| 39 | Unclassified | Intact | 3.5 | 3 | 8 hole/1 IF |
| 50 | SER II | Intact | 4 | 1.5 | 6 hole/1 IF |
| 59 | Unclassified | Intact | 4 | 2.5 | 10 hole/2 IF |
| 29 | SER II | Intact | 4 | 3 | 6 hole/1 IF |
| 30 | SER II | Intact | 4 | 3.5 | 6 hole/3 IF |
| 44 | SER II | Intact | 4 | 3.5 | 5 hole/1 IF |
| 40 | PER IV | Ruptured | 4 | 2 | 8 hole/2 IF/2 synd |
| 75 | PER III or IV | Ruptured | 4 | 3 | 10 hole/2 IF |
| 76 | PER IV | Ruptured | 4 | 3 | 2 synd |
| 65 | SER II | Partial rupture | 4 | 2 | 5 hole/1 IF |
| 26 | SER II | Intact | 4.5 | 3 | 6 hole/1 IF |
| 29 | SER IV | Intact | 4.5 | 3 | 8 hole/1 IF/1 synd |
| 32 | SER II | Intact | 4.5 | 3 | 6 hole/1 IF |
| 77 | SER IV | Ruptured | 4.5 | 2 | 5 hole |
| 33 | PER III or IV | Intact | 5 | 2.5 | 2 synd |
| 44 | SER II | Intact | 5 | 2.5 | 5 hole/THP |
| 17 | SER II | Intact | 5 | 3 | 7 hole/1 IF |
| 63 | SER II | Intact | 5 | 3 | 7 hole/1 IF |
| 22 | Unclassified | Intact | 5 | 3.5 | 2 synd |
| 52 | SER IV | Ruptured | 5.5 | 3 | 1/3 tub plate/1 IF |
| 65 | SER II | Intact | 6 | 2 | 6 hole/1 IF |
| 26 | SER II | Intact | 6 | 3.5 | 5 hole/1 IF |
| 58 | SER II | Ruptured | 6 | 3 | 6 hole/1 IF |
| 47 | SER IV | Ruptured | 6 | 4 | 6 hole/1 IF |
| 21 | SER IV | Ruptured | 7 | 3 | 6 hole/1 IF |
| 33 | PER IV | Ruptured | 7 | 2.5 | 2 synd |
| 16 | PER IV | Ruptured | 8 | 3 | 8 hole/1 IF/1 synd |
| 32 | SER IV | Ruptured | 8 | 3.5 | 7 hole/1 IF |
| 26 | PER IV | Ruptured | 10 | 6 | 10 hole/3 IF/1 synd |
| 76 | SER IV | Ruptured | 12 | 3 | 6 hole/1 IF |

**Abbreviations:** hole, 1/3 tubular plate; IF, interfragment screw; K-wire, Kirschner wire; synd, syndemosis screw.

**TABLE 2 Radiographic Lauge-Hansen classification versus arthroscopic deltoid ligament integrity**

| Fracture Type | Number of Intact Deltoid | Number of Ruptured Deltoid |
|---|---|---|
| SER II | 20 | 1 |
| SER III | 1 | 0 |
| SER IV | 1 | 6 |
| PER III/IV | 1 | 1 |
| PER IV | 0 | 5 |
| Unclassifiable | 3 | 0 |

The experiments of Ramsey and Hamilton (48) and Yablon et al (2) established the notion that even small amounts of talar shift and fibular displacement require open reduction and internal fixation to prevent abnormal surface pressures on the ankle joint. Harper (18, 44) later showed with manual stressing that the lateral malleolus and supporting ligamentous structures were the primary restraint against lateral talar shift, with the deep deltoid ligament acting as a secondary restraint. However, these studies were all conducted on the static unloaded ankle and therefore represent a nonphysiologic model.

More recent biomechanical studies in axially loaded ankle models demonstrate that in the absence of a medial ankle injury, the talus remains centered beneath the tibial plafond and stable in the ankle mortise with normal loading forces regardless of a displaced lateral malleolar fracture at or above the joint level, even with complete disruption of

**TABLE 3 MCS corresponding to deltoid ligament integrity**

| MCS (mm) | Number of Intact Deltoid | Number of Ruptured Deltoid |
|---|---|---|
| 1.0 | — | — |
| 2.0 | — | — |
| 2.5 | 3 | — |
| 3.0 | 4 | — |
| 3.5 | 4 | — |
| 4.0 | 5 | 3 |
| 4.5 | 3 | 1 |
| 5.0 | 5 | — |
| 5.5 | — | 1 |
| 6.0 | 2 | 2 |
| 7.0 | — | 2 |
| 8.0 | — | 2 |
| 9.0 | — | — |
| 10.0 | — | 1 |
| 11.0 | — | — |
| 12.0 | — | 1 |

the syndesmosis (29, 30, 32–34, 49). In the unconstrained loaded ankle model, deltoid disruption increases talar instability in the direction of anterolateral rotation in the ankle mortise with a significant decrease in tibiotalar contact area (1, 28, 30, 31, 34). This suggests that the deltoid ligament is the primary stabilizer of the loaded ankle, supporting the theory that ankle stability is, in fact, determined by medial injury.

Arthroscopy has been used in the past to assess cartilage lesions and ligamentous damage in acute ankle fractures (50). Hintermann et al correlated lesions of the deltoid, anterior talofibular, and anterior tibiofibular ligaments with fracture type, according to the AO/ASIF Danis-Weber classification (50, 51). In that study, the majority of deltoid ruptures occurred in type B fractures. The MCS was not measured on radiographs or associated with deltoid integrity, although 1 illustrative case showed a widened medial mortise with an intact deep deltoid ligament. Another study evaluated patients with chronic ankle instability and found that, of 54 patients with arthroscopically discernable medial instability (defined by deltoid ligament rupture and ≥5 mm lateral talar displacement assessed by arthroscopic instrumentation), only 36 were clinically diagnosed with medial instability on the basis of symptoms and pain on examination (52). Rotational instability—defined by medial and lateral symptoms—was determined athroscopically in 38 patients, but was clinically determinable in only 18 patients (52). However, this series excluded all fractures and did not take MCS measurements or correlate stress radiographs with arthroscopic findings. Nevertheless, it provides valuable arthroscopic information regarding collateral ankle ligament injuries. Our study evaluated deltoid ligament integrity with direct arthroscopic visualization and then correlated it with widening of the MCS on standard radiographs (Figs. 1 and 2).

**FIGURE 2** Deep deltoid ligament rupture.

This study was designed to evaluate the reliability of standard radiographs of displaced lateral malleolar fractures in predicting deltoid ligament integrity. In this investigation, the deep deltoid ligament was intact 66.6% of the time despite MCS displacements ranging from 2.5 to 6 mm. These measurements represent larger amounts of maximal lateral talar displacement with deep deltoid constraint than previously shown by both cadaver models and clinical studies (8–15, 17–21). None of these investigations compared deep deltoid ligament integrity with corresponding MCS measurements in the clinical setting. Pankovich and Shivaram (14) reported intraoperative evidence of deep posterior tibiotalar ligament rupture in 15 cases in which the MCS was >2 to 3 mm, but exact MCS measurements for deltoid ruptures are not provided. Similarly, Harper (19) operatively examined deltoid ruptures in 4 of 26 cases in which the MCS was ≥5 mm on stress radiographs.

The radiographic criterion for deltoid ligament rupture is variable and based largely on cadaver experiments. The landmark work of Close (11) established the importance of the deep deltoid ligament in limiting lateral talar shift, with only 2 mm of possible displacement noted in a cadaver model. Other authors in that era supported his findings (8, 10, 12). Harper (18, 44) later showed that, in the absence of the lateral malleolus, lateral talar shift after manual stress averaged 1.9 mm (range, 1.5 to 3 mm) with an intact deep deltoid. This distance increased to an average of 3.8 mm (range, 3 to 4.5 mm) after deep deltoid division despite an intact superficial deltoid; anterior talar displacement similarly increased. Historically, the radiographic criterion for deep deltoid rupture was an MCS widening beyond 2 to 3

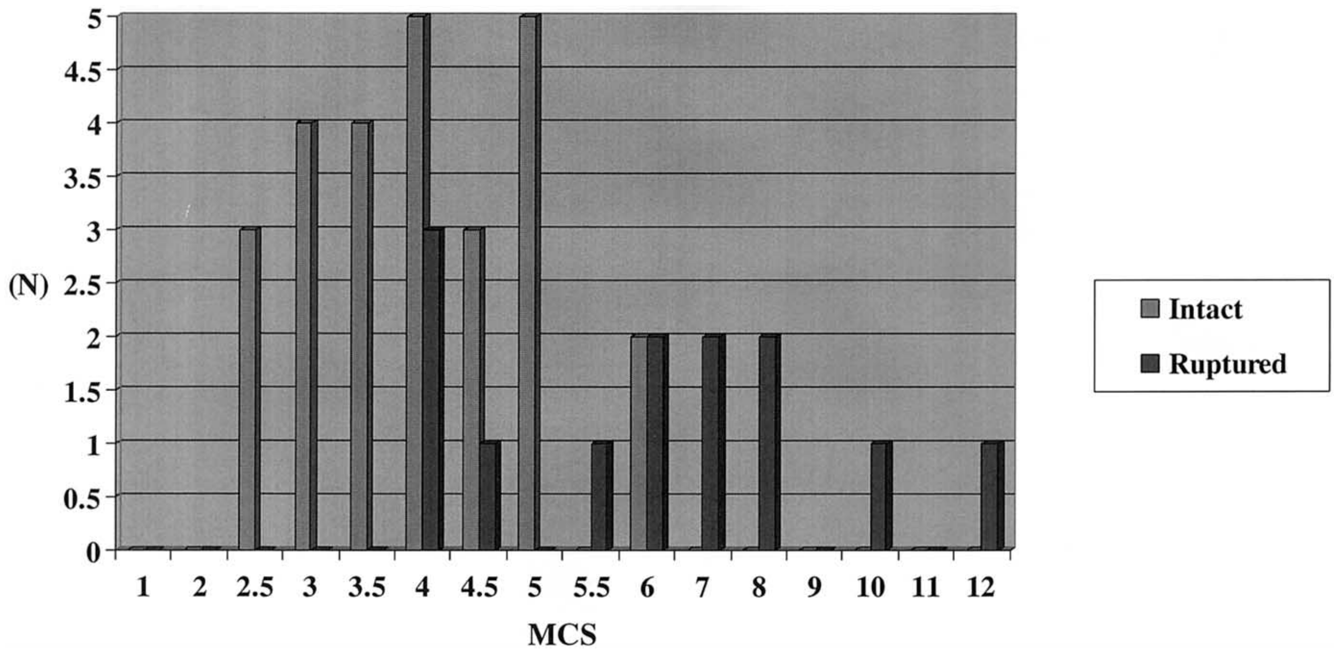


**FIGURE 3** Graphic distribution of ruptured and intact ligaments over the range of MCS widening. Note the overlap of intact and ruptured ligaments in the range of clear space widening from 4 to 6 mm. N, number of ligaments.

mm (9, 13, 14). During the past 2 decades, authors have proposed diagnosis of deep deltoid rupture if the MCS is ≥5 mm on stress radiographs (19), ≥5 mm on stress radiographs with medial ankle tenderness (53), or wider than the superior joint space with medial ankle tenderness (17).

Of special interest in this study is that, in those patients with a preoperative MCS range of 4 to 6 mm, the deep deltoid was intact twice as often as it was ruptured (Fig. 3). In fact, deep deltoid rupture was not found in any preoperative MCS measurement <4 mm, and 2 deep deltoid ligaments were found to be intact at an injury MCS measurement of 6 mm. These data refute much of the existing radiographic criteria that establish a deep deltoid rupture. Because convention suggests that an MCS of 3 to 5 mm or greater indicates deltoid rupture, the predictive value of injury MCS measurements for deltoid rupture was determined for the range of ≥3 to 6 mm. The data show that 88.5% of deltoid ligaments presumed ruptured at an injury MCS of ≥3 mm were actually intact, although this was not significant. At an injury MCS of ≥4 mm, the false positive rate for deltoid ruptures was significant at 53.6%. The false positive rate was 26.9% and 7.7% for MCS measurements of ≥5 mm and ≥6 mm, respectively. These data suggest that deltoid ligament integrity cannot be reliably predicted if the MCS on injury radiographs measures between 4 and 6 mm.

Based on this study, it would seem that the most common radiographic sign of deltoid ligament rupture and medial ankle instability therein is unreliable. The finding that more deep deltoid ligaments were intact at a 4-mm threshold should not be a foundation for raising the radiographic threshold for nonsurgical treatment of displaced lateral malleolar fractures. Rather, the combined MCS range of 2 to 6 mm represents a wide range of uncertainty for deltoid integrity and implies that further scrutiny of the medial soft-tissue injury is required in fractures of the lateral malleolus.

Stability of a displaced lateral malleolar fracture cannot always be determined by radiographic signs alone. It is generally accepted that clinical signs of medial ankle soft-tissue injury with lateral malleolar fracture and significant lateral talar displacement on radiographs—evidenced by 6 mm or more according to this study—constitute an unstable ankle fracture for which surgical treatment is advised (3, 4, 16, 54–57). By contrast, patients who sustain a lateral malleolar fracture but do not present with medial ankle tenderness generally have a stable ankle injury, for which conservative treatment produces acceptable outcomes (5–7). Unfortunately, clinical examination may underestimate medial ankle injury in some circumstances. A recent arthroscopic study showed only 36 patients had a clinically presumed deltoid injury before surgery when it was actually confirmed in 54 cases (52). Moreover, patients with an isolated lateral malleolar fracture and medial ankle tenderness in the absence of obvious lateral talar shift also present a clinical challenge. Such circumstances call for careful diagnostic measures to rule out unstable ankle injuries.

Arthroscopic evaluation of the deep deltoid ligament in patients with a widened MCS is not a practical diagnostic modality. Assessing deltoid ligament integrity with stress

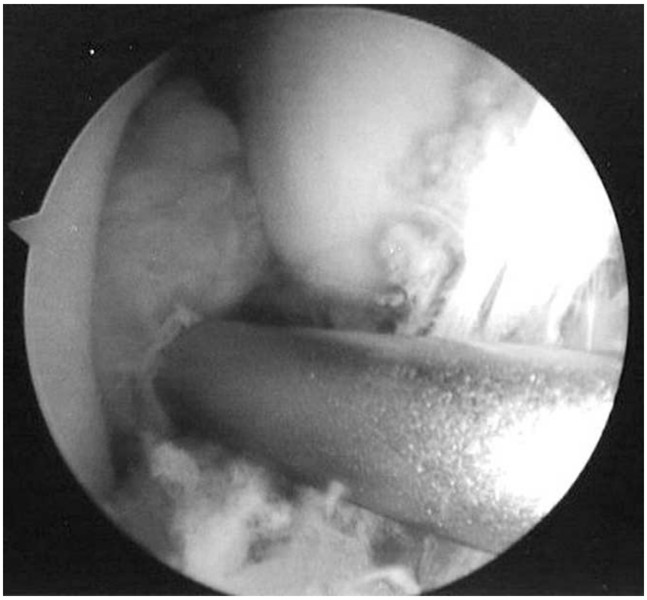

**FIGURE 4** Intraoperative arthroscopic image of a right ankle. The probe is along the inferior margin of the deep deltoid ligament, which is intact.

radiography or fluoroscopy is probably more practical, yet the sensitivity and specificity of these measures have not been evaluated (20). In the present study, 1 intraoperative stress radiograph showed a MCS of 6 mm, but, in this case, the deep deltoid ligament was intact (Fig. 4). Magnetic resonance imaging and ultrasound have been used to assess lateral ankle ligaments with little or no attention to deltoid ligament trauma (20). However, a recent cadaver study established a simple radiographic method termed the "gravity-stress view" that was 100% sensitive and specific for the diagnosis of deep deltoid rupture in the setting of a lateral malleolar fracture (20). This appears to be the only noninvasive imaging method that can accurately determine deep deltoid integrity when rupture is suspected, although the question of clinical usefulness remains.

The results of this study show that the Lauge-Hansen classification scheme is not always accurate in establishing deltoid ligament rupture based on radiographic appearance and expected rotational fracture pattern, particularly in SER injuries. In 3 of 40 fractures, the integrity of the deltoid ligament was opposite of the expected finding. In 1 case, arthroscopic visualization showed a deltoid rupture in a patient, with radiographs consistent with an SER-II, given the absence of lateral talar displacement. In another case, the MCS was measured at 4.5 mm, presumed to be an SER-IV fracture, but, in fact, the deltoid ligament was intact. Cedell (13) observed that distinguishing between SER-IV, SER-III, and even SER-II injuries can be, "very difficult or even impossible" by radiography. In a series of 417 SER injuries, Cedell (13) observed deltoid rupture in only 25% of SER-IV fractures and criticized Lauge-Hansen's work for the inadequate attention paid to the clinical evaluation of these injuries. Other short- and long-term follow-up series of conservatively treated SER-II–type injuries attribute a few disappointing outcomes to the erroneous inclusion of SER-IV fractures (5–7, 58). The Lauge-Hansen classification alone may not be the most accurate means to determine stability in SER injuries in which medial ligament damage is in question.

Although the Lauge-Hansen system is not infallible, 91.6% of the fractures in this study classifiable according to the scheme demonstrated the expected deltoid ligament findings. Yde (59) presented a favorable review of the Lauge-Hansen classification, in that 98.8% of 488 malleolar fractures were classifiable according to the system, although the medial malleolar and deltoid ligament injuries were not all characteristic of SER and pronation-type fracture patterns. Although use of the Lauge-Hansen classification accurately determined most fracture patterns in the present study, it has been shown that the system cannot be applied consistently among users, with only poor to fair interobserver reliability (53, 60–62). Modifications of the Lauge-Hansen scheme may escalate the degree of accuracy in predicting medial stability in ankle fractures. The radiographic fracture pattern might be correlated with clinical findings and additional diagnostic evaluation of deltoid ligament integrity.

The problem of inconsistent application of the Lauge-Hansen scheme is compounded by fractures patterns that escape this classification system altogether. In this study, 3 of 40 ankle fractures did not fit into any of the established patterns. Each of these injuries showed a fibular fracture proximal to the tibiofibular syndesmosis suggestive of a PER injury but in fact the deep deltoid ligament was intact. Pankovich (63, 64) showed the occurrence of SER fractures above and below the anterior fibular tubercle along with several atypical fracture patterns at the distal tibiofibular syndesmosis. He also established that SER, PER, and pronation-abduction injuries produced fibular fractures above the syndesmosis, refuting Lauge-Hansen's belief that all fibular fractures at this level were PER injuries (64, 65). An experimental study that reproduced Lauge-Hansen's SER fracture pattern showed not only that this pattern could not be replicated by SER mechanism but also, more importantly, that the, "relationship of radiologically occult injuries in the classic supination and external rotation type fracture is not consistently predictable based on the fracture pattern observed. This implies that strict reliance on fibular fracture configuration to assess ankle instability is not warranted" (27). The findings of the present study corroborate the limitation of the Lauge-Hansen classification to accurately characterize all fracture patterns and to predict deltoid ligament integrity.

The decision to manage a seemingly innocent SER-II fracture nonsurgically, without accurate assessment of medial injury, may predispose a patient to the sequelae of nonanatomic ankle mortise reduction, including early degenerative arthritis, fibular malunion, and mortise instability (3, 21, 54–57, 66). Rupture of the deltoid ligament in the setting of a displaced lateral malleolar fracture is biomechanically equivalent to a bimalleolar fracture (30). This injury is best treated with open reduction and internal fixation of the fibula to restore mortise anatomy; exploration of the medial ankle and deltoid repair is probably unnecessary (3, 7, 16, 17, 19, 21, 54, 56, 57, 67). The results of this study may encourage careful evaluation of medial ankle injury in displaced malleolar fractures and may stimulate new investigations for questions that remain unanswered in this challenging injury. On the other hand, whether one uses radiographic, clinical, or other criteria to specifically determine deltoid ligament integrity, exact diagnosis may not be important if the threshold for surgical fracture reduction is low.

There are number of limitations in this study. The contribution of the superficial deltoid ligament was not evaluated because this structure could not be seen by the arthroscopic approach. In the unconstrained axially loaded ankle model with syndesmosis disruption and stabilization of the simulated fibular fracture, the superficial deltoid has been implicated as a contributing restraint against external rotation of the talus in plantarflexion (34). However, the deep deltoid ligament shows greater contribution to talar stability in the ankle mortise because transecting the superficial deltoid does not disrupt normal axial ankle kinematics (1). The deep deltoid ligament was defined by the deep posterior tibiotalar component based on the results of anatomic investigations documenting its prevalence (35–40). Moreover, this ligament was the only component of the deep deltoid that was easily identified by arthroscopy given its intraarticular accessibility. In some cases, the deep anterior tibiotalar ligament may have been present, although it was not often appreciated, consistent with anatomic investigations (37). With open exploration of deep deltoid rupture, others have found its identification difficult given its small size and the surrounding damage (14).

Partial tears of the deep deltoid ligament were not considered in this study, in large part because only 1 such case was appreciated. Of the 26 deep deltoid ligaments found to be intact, some partial tears were probably present but their significance cannot be determined. The presence of partial tears or attenuated ligaments could account for the larger MCS measurements than the 3 to 5 mm observed in the majority of fractures with intact deep deltoid ligaments (Table 3). In this study, 29 fractures were classified as SER-type injuries. A separate arthroscopic study of acute ankle fractures found most partial deltoid ligament ruptures to be associated with Weber B fracture patterns, corresponding to Lauge-Hansen SER injuries, but the number of complete deltoid ruptures exceeded partial ruptures (50). However, there is no evidence to suggest that a partial tear of the deep deltoid ligament confers medial ankle instability in the presence of a displaced lateral malleolar fracture.

Another explanation for larger MCS measurements than expected in fractures with an intact deep deltoid ligament includes arthroscopic error, radiographic MCS measurement error, and radiographic magnification errors. Although the presence of partial deep deltoid tears could not be ruled out in all cases, the senior surgeon had sufficient experience to assess the deep deltoid ligament integrity. Although the fractures were surgically treated within 1 week after injury, some of the subtle indicators of ligamentous injury may have dissipated by the time of surgical inspection. Subjectivity can also skew results somewhat with regard to radiographic fracture classifications according to Lauge-Hansen, although 2 of 3 authors evaluated all injury radiographs and agreed on each fracture pattern.

Finally, the method of MCS measurement can be scrutinized. All measurements were obtained on the ankle mortise radiograph, which has been shown to permit the most accurate evaluation of mortise widening and is favored by some authors (17, 41). However, given the retrospective nature of this study, it was impossible to determine whether each mortise radiograph was positioned precisely at 15° to 20° of internal rotation. It is unlikely that this influenced measurements to a significant degree. MCS measurement technique was performed according to convention (10, 15). However, Pankovich (64) observed that the superior and MCSs were equivalent only when the latter was measured "between the junction of the medial malleolus and the plafond and the lateral border of the talus and the plafond," in normal ankles. In other words, inaccuracies may exist when the MCS is determined more inferior on the medial surface. Measurements between the medial aspect of the talus and medial malleolus were often 2 to 5 mm wider than the superior joint space, especially on stress radiographs (64). Even so, the measurement method in this study was identically performed on each radiograph. It is unlikely that our method produced markedly wider MCS values, particularly when considering the superior joint margin for comparison. This was still considerably smaller than the MCS measuring point proposed by Pankovich (64) even in cases where the deep deltoid was intact despite presumed rupture (Fig. 4). It is also possible that some patients had an abnormally wide MCS before injury, although this could not be determined because contralateral films of the noninjured ankle were not evaluated.

## Conclusion

Displaced lateral malleolar fractures in patients with medial ankle tenderness, but without overt widening of the MCS, require careful attention. Accurate diagnosis of deltoid rupture in this injury by noninvasive means remains a clinical challenge. The results of this study suggest that deltoid ligament integrity cannot be reliably predicted by the MCS on injury radiographs of displaced lateral malleolar fractures. MCS variability in these injuries should raise suspicion for an unstable fracture and prompt a thorough assessment for the presence of medial injury.


## Acknowledgment

The authors thank Eugene Zarutsky, DPM, for initial data analysis, and Dr Lynn Ackerson for the final statistical analysis.


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