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Systematic Review of Stress Radiographic Modalities Stability Assessment in Supination External Rotation Ankle Fractures

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Abstract

Background: Isolated distal fibular fractures resulting from supination external rotation (SER) injuries without evidence of obvious talar shift on standard radiographs present a diagnostic dilemma for clinicians. The status of the deep deltoid ligament, the main stabilizer of the ankle joint, is assessed by an increase in medial clear space (MCS) on radiographs. Therefore, these injuries can be either stable or unstable. In recent years, considerable clinical and research efforts have been made to determine ankle stability following SER fracture. The purpose of this systematic review was to evaluate and compare the role of different stress radiograph modalities in assessing stability of the ankle with SER fractures with no obvious talar subluxation on standard radiographs.

Methods: The electronic databases MEDLINE, EMBASE, Ovid, Cochrane Central, CINAHL, and Google Scholar were searched from January 2000 to January 2018 to identify literature relating to radiologic assessment of stability of SER ankle fractures.

Results: Our literature search revealed 10 peer-reviewed articles that fulfilled inclusion criteria. This yielded a total of 698 patients. The systematic review found 3 broad categories of radiographic investigations in the assessment of ankle joint stability: external rotation (ER) stress radiographs, gravity stress views (GSV), and weightbearing (WB) radiographs. Proponents of WB radiographs have demonstrated how axial load can normalize ankle joint alignment in cases of proven instability. There was a consistently high grade of evidence for using a medial clear space (MCS) value of more than 4 to 5 mm to indicate an unstable ankle following SER fracture.

Conclusion: In conclusion, the results of this systematic review support an MCS value of less than 4 to 5 mm as a good indicator of stability, regardless of choice of stress imaging modality. These patients can be allowed early weightbearing with expected good functional outcomes. Recent published literature favors WB stress radiographs as a reliable and safe technique for assessing stability in SER ankle fractures. However, it should be kept in mind that this is based on studies with relatively low grades of evidence.

Level of Evidence: Level II, systematic review of variable quality studies.

Keywords: ankle fractures, stress radiographs, stability, supination external rotation

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Introduction

The ankle is defined as unstable if the injury pattern of the fractured ankle allows external rotation of the talus. This is seen as lateral shift of the talus or an increase in the medial clear space (MCS) on standard radiographs.[17,23] There is a general consensus that the deltoid ligament, in particular, is vital for preventing subluxation of the talus after an isolated lateral malleolus fracture.[18] This is also the basis of the Lauge-Hansen classification system in which supination external rotation (SER) IV injuries were differentiated from SER II injuries by the presence of medial instability, that is, a medial malleolus fracture or deltoid ligament rupture.[6,29] Assessment of stability in isolated distal fibular SER fractures with possible deltoid ligament injury and no obvious talar shift poses a diagnostic challenge.[2,3] The patterns of instability may not be apparent on standard radiographs.[2,3,13,29] Fractures with suspected deltoid ligament injury require careful evaluation and treatment, as inability to maintain anatomical alignment of the ankle has clinical and biomechanical implications with potential for poor outcomes.[6,24] Stable SER fractures can effectively be treated nonoperatively with functional bracing and early mobilization.[6,9]

Clinical signs are not considered reliable predictors of stability or deltoid ligament incompetence.[3,20] The presence of medial tenderness, swelling, and ecchymosis may be suggestive of superficial deltoid injury, not necessarily ankle instability.[4,16] Increased focus on stress radiographs has helped to improve our ability to determine SER fracture stability but there remains debate as to which imaging technique is most useful.[25,30] The purpose of this systematic review was to evaluate and compare the role of different stress radiographic modalities in assessing stability of the ankle in patients with SER-type fractures with no obvious talar subluxation on standard radiographs.

Various methods have been used to assess ankle stability with stress radiographs. ER stress radiographs are perhaps one of the most extensively used techniques used to assess stability.[4,16,22] As described by McConnell et al,[16] these are performed with the leg stabilized in approximately 10 degrees of internal rotation with the ankle in neutral dorsiflexion while an external force of approximately 8 to 10 lb is applied to the ankle.

Gravity stress views have also been described. In 2001, Michelson et al[19] performed a cadaveric study that proposed gravity stress views (GSV) as integral in the detection of ankle joint instability. The patient is positioned in the lateral decubitus position, on the side of the injury, with the distal half of the leg off the end of the table. A standard anteroposterior and mortise view is then taken at approximately 10-degree internal rotation of the tibia (Figure 1), as described by Michelson et al.[19]

Weightbearing/axial load radiographs have also been used to assess ankle stability after lateral malleolus fracture. In 2010, Weber et al[30] proposed the use of WB radiographs. The WB technique is shown in Figure 2. The patient should

Figure 1. Assessment of ankle joint instability detection using the gravity stress view technique.

Figure 2. Assessment of ankle joint instability detection using the weightbearing technique.

stand on both legs as pain allows, with the weight equally distributed and the foot in a dorsiflexed position while the anteroposterior, mortise, and lateral images are taken.[11,30]

Various other nonradiographic methods have been described. Magnetic resonance imaging (MRI) scanning has been used to assess the integrity of the deep deltoid ligament to distinguish between stable and unstable SER fractures by a few researchers.[2,12,21] No correlation was found between deep deltoid ligament integrity as seen on MRI scans and the results on stress radiographs. There have been reports of preliminary WB cone beam CT scans for assessing the stability of SER fractures.[15] No clinical correlation has been made. This imaging modality may be used more frequently in the future. Few studies have highlighted the role of ultrasonography to assess the deltoid ligament following SER fracture.[1]

Methods

The identification of relevant publications for this systematic review was performed by a comprehensive electronic literature database search using MEDLINE, EMBASE, Ovid, Cochrane Central, CINAHL, and Google Scholar according to PRISMA-P 2015 Group guidelines.[27] A combination of MeSH (controlled terms used in the MEDLINE database to index citations), MeSH-like terms (controlled terms for other similar databases, eg, EMBASE) and free text words were used to search for relevant studies according to the PICOS[28] approach. Original studies published in peer-reviewed journals were identified. Full papers were examined and studies meeting the research question were included. The final included studies for review were assessed for quality of evidence using a validated 5-level quality assurance tool from the Centre of Evidence Based Medicine at Oxford University and were graded for quality according to the framework provided by GRADE.[8] The final list was collated with the help of a reference manager software program by the name of EndNote x8 (Thomson Reuters, Philadelphia, PA). Data collection was performed on a Microsoft Excel format using a data extraction form. Attention was paid to the study design in selected studies, and an assessment of possible bias was undertaken. To our knowledge, no systematic review has been performed to evaluate and compare the different stress-radiographic modalities.

Inclusion Criteria

Preliminary research showed that gravity stress views and weightbearing radiographs, the 2 most commonly used methods, were only assessed after the year 2000, hence our inclusion of papers within this time frame. All peer-reviewed publications in the English language relating to the assessment of stability of SER fractures with stress radiographs were included. To yield sufficient data, only those studies with at least 25 adult participants were counted.

Exclusion Criteria

All literature in languages other than English were excluded. Studies focusing on CT scans, MRI, ultrasonography, and intraoperative findings to assess stability were excluded. Cadaveric studies were not considered for this review.

Summary of Measures

The literature search revealed a predominance of cohort studies with an absence of randomized controlled trials. A strict methodology for paper selection was initially applied, with a focus on different testing modalities compared to a gold standard. This, however, had to be revised as none of the available papers fulfilled the desired criteria. The lack of uniformity rendered it impossible to directly compare different techniques. Results are reported in quantitative terms where possible, but due to these limitations most are presented in narrative or tabular form.

Results

From January 2000 to January 2018, 10 peer-reviewed articles fulfilled our inclusion criteria. This yielded a total of 698 patients (Figure 3). One of the studies (McConnell et al[16]) was not gender specific but from the remaining patient cohort of 560 patients, 52.6% were female. A detailed account of the patient demographics is presented in Table 1. Three broad categories of radiological assessment were identified: ER stress radiograph, GSV and WB radiographs. Eight studies were prospective and 2 were retrospective. It was noted that there was a relatively short period of follow-up in almost all of the studies. The only exception was one study that had more than 2 years' follow-up with a relatively small number lost to follow-up (8 percent).[30]

Increased MCS was the most consistently used parameter of instability across all included studies. There was a lack of uniformity regarding techniques used to measure MCS radiologically. All but one study[20] used a cut off value of 4 mm as a predictor of instability; the exception used a cut-off value of 5 mm (Table 2). Two of the most recently published studies used a cut off value of 7 mm as a marker of gross instability and recommended no further stress imaging.[10,26] There was a consistently high grade of evidence for using an MCS value of more than 4 to 5 mm to indicate an unstable ankle following SER fracture.

There were no randomized controlled trials, and only 1 study was designated Level I evidence. This study was published by Gill et al[5] concluding that the GSV is equivalent to ER stress radiographs in determining instability as well as deltoid ligament injury in patients with SER fracture. Equivalent diagnostic accuracy of GSV and ER stress radiographs in diagnosing stable SER fractures was reported in all prospective comparative studies with grades of evidence

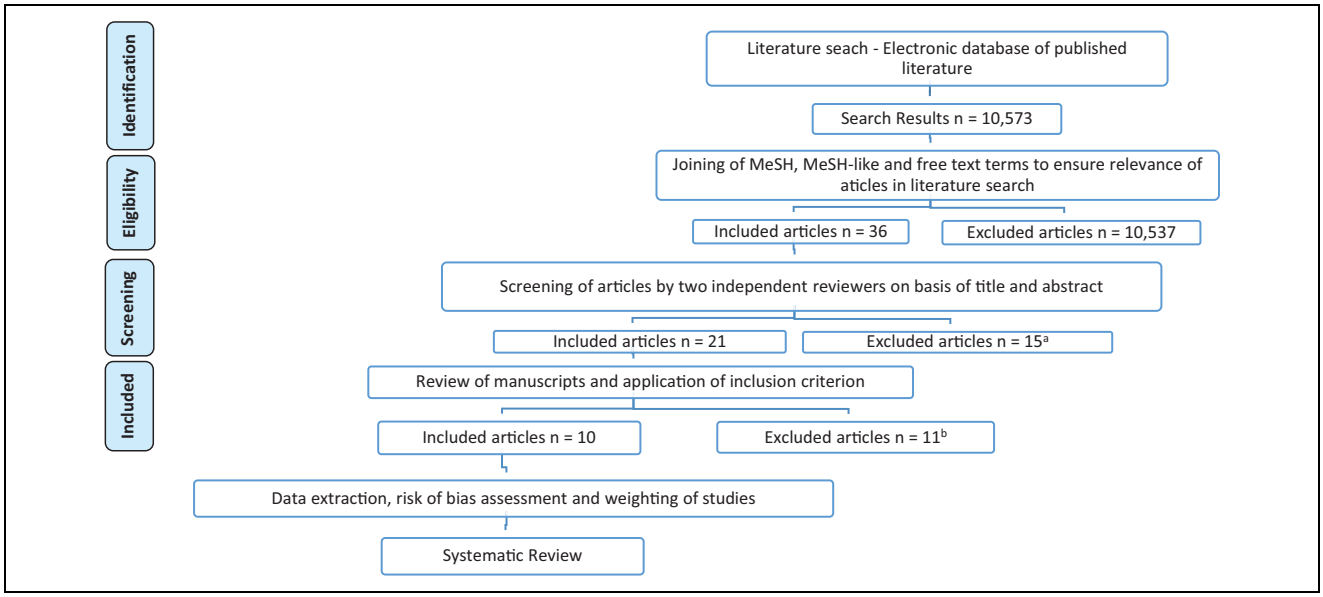

Figure 3. PRISMA flow chart.
[a]Of the 15 excluded articles at this stage, 12 were duplicates, 1 study failed to meet desired number of patients included in study, and 2 studies were intra-operative assessments and thus did not meet the criteria.
[b]Of the 11 excluded articles at this stage, 4 were MRI related, 3 were cadaveric studies, 2 were Ultrasound studies, 1 arthroscopic and 1 commentary with follow up measure but without intervention.

Table 1. Patient Demographics.

Author/Study/ Year	No. of Patients	Demographics	Time of Follow-up	% Lost to Follow-up	Complications
McConnell et al[16] 2004/USA	138	Not provided	6 mo minimum	8	None reported
Egol et al[4] 2004/USA	101	Male/female = 44:57 Mean age = female: 42.3; male: 37.3	7 mo on average	N/A	2 patients complaining of pain; 1 patient received workers compensation
DeAngelis et al[3] 2007/USA	55	Male/female = 26:29 Mean age = 42	Diagnostic study only, without clinical follow-up	N/A	N/A
Gill et al[5] 2007/USA	25	Male/female = 12:13	Diagnostic study only without clinical follow-up	N/A	N/A
Schock et al[25] 2007/USA	29	Male/female = 17:12 Mean age = 42	Diagnostic study only without clinical follow-up	N/A	N/A
Nortunen et al[20] 2015/Finland	79	Male/female = 42:37 Mean age = 44	Diagnostic study only without clinical follow-up	N/A	N/A
Weber et al[30] 2010/Switzerland	78	Male/female = 40:38 Mean age = 46	18-120 mo (mean 62 mo) follow-up	8	1 delayed wound healing (6 mo)
Hoshino et al[11] 2012/USA	38	Male/female = 20:18 Mean age = 28	Minimum 6 mo, average 12 mo	29	1 asymptomatic fibrous union of distal fibula
Holmes et al[10] 2016/USA	51	Male/female = 63%:37% Mean age = 49.8	Minimum 12 mo	43	1 increase in MCS in 1-y follow-up
Seidel et al[26] 2017/Germany	104	Male/female = 64:40 Mean age = 48	Minimum 1 y, average 23 mo	8.9	1 nonunion (3.6%) in GS stable group 2 nonunions (5.9%) in GS unstable group

Abbreviations: GS, gravity stress; MCS, medial clear space; N/A, not applicable.

Table 2. Quality of Evidence.

Author/Study/ Year	Study Design	Evidence Level	Intervention
McConnell et al[16] 2004/USA	Prospective, multicenter	II	ER stress radiographs at time of injury to distinguish between SER II and SER IV fracture
Egol et al[4] 2004/USA	Prospective, single-center	II	ER stress radiographs to distinguish between SER II and SER IV fracture
DeAngelis et al[3] 2007/USA	Prospective, comparative single-center	III	ER stress radiographs vs medial malleolar tenderness
Gill et al[5] 2007/USA	Prospective, comparative, blinded, randomized, single-center	I	GSV vs ER stress radiographs at time of injury to distinguish between SER II and SER IV fracture
Schock et al[25] 2007/USA	Prospective, comparative, single-center	II	GSV vs ER stress radiographs and patient tolerance of these at time of injury to distinguish between SER II and SER IV fracture
Nortunen et al[20] 2015/Finland	Prospective, comparative, single-center	III	GSV + clinical signs vs ER stress radiographs (as gold standard) to distinguish between SER II and SER IV fracture
Weber et al[30] 2010/Switzerland	Retrospective case series, single-center	IV	WB radiographs to distinguish between SER II and SER IV fracture
Hoshino et al[11] 2012/USA	Prospective, comparative, single-center	III	WB radiographs to distinguish between SER II and SER IV fracture
Holmes et al[10] 2016/USA	Retrospective, single-center	IV	WB radiographs vs GSV to distinguish between SER II and SER IV fracture
Seidel et al[26] 2017/Germany	Prospective, single-center, comparative	III	WB radiographs vs GSV to distinguish between SER II and SER IV fracture

Abbreviations: ER, external rotation; GSV, gravity stress views; SER, supination external rotation; WB, weightbearing.

ranging from I to III (Table 2). However, GSV was perceived to be more tolerable by patients compared with ER stress radiographs (Table 3).

The grade of evidence for studies based on WB radiographs was mostly III or IV. In the reported literature, there was a clear shift from GSV in the early 2000s to WB radiographs from 2010 onward after the publication by Weber et al.[30] The subsequent WB radiographic studies demonstrated low risk to failure of treatments with WB diagnostic algorithms and functional treatment. All WB studies consistently observed that the GSV stress views appear to overestimate ankle instability. In addition, proponents of WB radiographs have shown that axial load can normalize ankle joint alignment in proven unstable ankles. A direct comparison of WB radiographs with either GSV/ER stress radiographs demonstrated that WB radiographs tend to be a safe and reliable method for estimation of stability.[10,11,26]

Discussion

Some of the key concepts regarding ankle stability stem from 3 seminal cadaveric studies. Lauge-Hansen[14] developed a classification system allowing predictions to be made based on mechanism and fracture pattern. Ramsey and Hamilton[24] highlighted the importance of normal tibiotalar kinematics; they demonstrated that 1 to 2 mm of talar shift results in a 40% reduction in tibiotalar contact area. Michelson et al[19] introduced the concept of gravity stress radiographs to identify talar shift in suspected deltoid ligament injury. Despite these, there remains much debate within the literature regarding what constitutes a stable ankle.

A cutoff value of 4 mm is widely accepted as an indicator of radiographic ankle joint instability that has been used by all except 1 study in this review. It was interesting to note that 2 studies used 7 mm of MCS on standard radiographs as a marker of gross instability and recommended no further imaging with stress radiographs in these cases. There is, however, no established consensus regarding techniques to measure the MCS. Not all studies have offered a standard method of measurement.[11,25] There is a lack of standardization during ER stress and GSV imaging due to a discrepancy of amount of force applied and positioning of the foot, respectively. In the same account, there has not been any clear description of how much weight would be considered appropriate for WB radiographs. There has been a general consensus among authors that the patient should stand on both legs as pain allows, with the weight equally distributed and the foot in a dorsiflexed position.[11,30] It was noted in this systematic review that a cohort of patients who demonstrate instability during GSV or ER stress views were stable on WB radiographs and subsequently had good clinical outcomes with nonoperative treatment and early mobilization.

A possible explanation is that the position of the foot at the time of examination dictates the measurement of the MCS on standard as well as stress radiographs.[7] When both components of the deltoid ligament are intact, external forces can be resisted and stress testing reveals a stable ankle joint. By contrast, in the case of rupture of the superficial component of the deltoid ligament, the ankle may not be able

Table 3. Summary of Results.

Author/Study/ Year	Intervention / Comparison Between Studies	Parameters of Instability	Author Conclusions
McConnell et al[16] 2004/USA	ER stress radiographs	>4 mm MCS / >1 mm SCS = deltoid ligament injury = instability of ankle mortise	Clinical findings (medial tenderness, ecchymosis, and swelling) are not predictive of deep deltoid ligament injury. ER stress radiographs can be used as a gold standard to assess ankle instability in SER fractures
Egol et al[4] 2004/USA	ER stress radiographs	>4 mm MCS = positive stress test	Positive ER stress radiographs with >4 mm of MCS but with no clinical symptoms can be treated nonoperatively with good or excellent outcomes. Clinical signs are not reliable in detecting instability.
DeAngelis et al[3] 2007/USA	ER stress radiographs vs medial malleolar tenderness	>4 mm MCS = deltoid ligament injury = instability of ankle mortise	Clinical findings (medial tenderness, ecchymosis, and swelling) are not predictive of deep deltoid ligament injury. ER stress radiograph is more useful to detect instability.
Gill et al[5] 2007/USA	GSV vs ER stress radiographs	>4 mm MCS/ >1 mm SCS = deltoid ligament injury = instability of ankle mortise	GSV is equivalent to ER stress radiographs in determining instability as well as deltoid ligament injury in patients with SER fracture
Schock et al[25] 2007/USA	GSV vs ER stress radiographs and VAS	>4 mm MCS / >1 mm SCS = deltoid ligament injury = instability of ankle mortise	GSV is as reliable and perceived as more comfortable than that of ER stress radiographs. GSV recommended to be the initial diagnostic screening test in detection of occult medial ligamentous injuries in SER fractures of the ankle
Nortunen et al[20] 2015/Finland	GSV + clinical signs vs ER stress radiographs	>5 mm MCS / >1 mm SCS = deltoid ligament injury = instability of ankle mortise	Equivalent diagnostic accuracy of GSV and ER stress radiographs in diagnosing stable SER fractures. Presence of medial tenderness in combination with a positive GSV is a reliable test for detection of instability of SER fracture. Both GSV and ER may exaggerate the need for operative treatment when compared to WB stress test.
Weber et al[30] 2010/Switzerland	WB radiographs	MCS >4 mm and/or > 1 mm SCS = deltoid ligament injury = instability of ankle mortise	The use of WB radiographs is an easy, pain-free, safe, and reliable method to exclude instability, hence the need for operative treatment. GSV appears to overestimate instability in SER fractures. Nonsurgical treatment with protected weightbearing shows good early outcomes.
Hoshino et al[11] 2012/USA	ER stress radiographs vs WB radiographs	MCS >4 mm and/or > 1 mm SCS = deltoid ligament injury = instability of ankle mortise	WB radiographs can be used to assess stability of the ankle mortise during an early postinjury period. WB radiographs are more reliable even in ER stress radiograph positive patients. Nonsurgical treatment with protected weightbearing shows good early outcomes.
Holmes et al[10] 2016/USA	WB radiographs vs GSV	MCS >4 mm = deltoid ligament injury = instability of ankle mortise If MCS >7 mm = grossly unstable, no stress test required	WB radiographs are predictive of stability in isolated Weber B ankle fractures. GSV using traditional measurement criteria may overestimate instability in these injuries. Nonsurgical treatment with protected weightbearing shows good early outcomes.
Seidel et al[26] 2017/Germany	WB radiographs vs GSV	MCS >4 mm = deltoid ligament injury = instability of ankle mortise If MCS >7 mm = grossly unstable, no stress test required	WB radiographs were a reliable method to evaluate stability, allowing successful nonoperative treatment with protective weightbearing. GSV radiographs indicated a higher number of presumed instabilities.

Abbreviations: ER, external rotation; GSV, gravity stress views; MCS, medial clear space; SCS, superior clear space; SER, supination external rotation; WB, weightbearing.

to resist the external rotational forces and therefore appears unstable on ER stress radiographs. During axial loading, even in the presence of a partial tear, the talus remains anatomically reduced within normal limits of MCS on WB radiographs.[13] This lends supports to the theory that ankle stability can be thought of as a spectrum rather than simply

stable or unstable, and perhaps further validation with higher levels of evidence would be required. Preliminary reports of WB computed tomography have recently been published with promising results. There may be a role for this modality in future assessments of stability.[15]

Conclusion

In conclusion, the results of this systematic review support an MCS value of less than 4 to 5 mm as a good indicator of stability, regardless of choice of stress imaging modality. There is consistent, high-grade evidence to support this. These patients can be allowed early weightbearing with expected good functional outcomes. Furthermore, this systematic review identified a subset of patients that may have a positive stress test on ER/GSV but who are stable on WB views.[10,11,26] If this position is maintained, the fractures are likely to heal in an anatomic position without any significant long-term complications. Recent published literature favors WB stress radiographs as a reliable and safe technique for assessing stability in SER ankle fractures. However, it should be kept in mind that this is based on studies with relatively low grades of evidence. Additional research with a longer follow-up period is needed to accurately evaluate complications and recommended weightbearing status.

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