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## Assessing Quality of Syndesmotic Reduction in Surgically Treated Acute Syndesmotic Injuries: A Systematic Review

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## ABSTRACT

There is no universal method with cutoff values for the assessment of distal tibiofibular joint reduction in acute syndesmotic injuries. It is important to detect malreductions because they may lead to impaired functional outcome and may demand reoperations. The aim of this study was to systematically review the literature to evaluate the appropriateness of different image techniques in determining syndesmotic malalignment. A literature search was conducted in Medline, Embase, and the Cochrane Library to search for articles assessing syndesmotic reduction. Excluded were articles where no criteria and/or measurements for syndesmotic reduction were provided, only normative values were provided and reviews. In total, 2157 articles were found, of which 1421 studies were screened for title and abstract after exclusion of duplicates. One hundred ten studies were eligible for full-text analysis. Of these, 61 were excluded. Three studies were added after screening the included references. Fifty-two studies were included, of which 32 were original publications and 20 were publications referring to the original publications. From the original publications, 14 used plain radiographs, 19 computed tomographic (CT) scans, and 5 used 3-dimensional CT scans (some authors used >1 modality in their study). For each modality, a large number of parameters and different cutoff values were reported. CT scanning is superior to plain radiography in the assessment of the quality of joint reduction. Parameters used the most were fibular position in the incisura and fibular rotation. The criteria for adequate reduction should at least include the position of the fibula in the incisura and rotation of the fibula, while ensuring adequate fibular length, all equaling or at least approaching the values of the uninjured contralateral side.

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Over the last decades the incidence of ankle fractures has increased (1). In approximately 20% of the patients with an ankle fracture, tibiofibular (TF) syndesmotic disruption is present (2). It is well-established that syndesmotic injuries have a strong relation with post-traumatic arthritis (3,4); as a result of this relationship, anatomic reduction of the TF syndesmosis is essential to minimize the risk of developing post-traumatic osteoarthritis (5,6). In addition, it has been found that malreduction of the syndesmosis leads to significantly worse functional outcomes (7,8).

Several controversies regarding treatment for syndesmotic injuries are present. A survey showed that there is a disagreement between (orthopedic) trauma surgeons regarding management of syndesmotic injury (9). For example, there is no consensus regarding the optimal

size and number of screws needed for syndesmotic reduction (4,10). Furthermore, it is unclear whether this syndesmotic screw needs to be removed after the syndesmosis has healed or removal is only indicated in case of symptomatic implants (eg, painful implants or restricted range of motion) (8,10). Retaining the syndesmotic screw requires anatomic fixation of the syndesmotic joint because improper fixation may lead to restricted range of motion or implant-related pain, which in turn mandates syndesmotic screw removal (11–13). It is important to note that the morphology of the incisura fibularis has been found to be associated with specific malreduction patterns (14,15). A shallow incisura is, for example, correlated with anterior fibular malreduction and a deep incisura is predisposed to posterior sagittal plane and rotational malalignment (15).

Currently, there is no universally applied method for confirming adequate reduction of the syndesmosis. As a result, malreductions may go undetected with possible diminished functional outcomes.

The aim of this article was to systematically review studies assessing the quality of distal TF syndesmosis reduction to evaluate the

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appropriateness of different image techniques in determining syndesmotomic malalignment. A secondary aim was to compare functional outcomes with anatomic versus nonanatomic reductions.

## Materials and Methods

This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. (16) A search of the online databases PubMed, Embase, and the Cochrane library was performed with the help of a clinical librarian using the following search terms: ankle fracture, ankle injury, distal tibiofibular joint, syndesmosis\*, (mal)reduct\*, computed tomograph\*, and radiograph\* (full search strings are available in the Supplemental Appendix). Each search term was modified to fit use in the different databases. Studies were screened by 3 different independent raters (S.v.d.H., S.D., and T.G.) using an online tool ([www.covidence.org](http://www.covidence.org)). Discrepancies between the raters were resolved through discussion, after which consensus was reached.

Based on title and abstract articles were eligible for inclusion in the study if:

1. They described acute syndesmotomic injuries (including simulated injuries),
2. Surgical fixation of the syndesmosis was performed (metal screw or reduction clamp). And
3. Intraoperative and/or postoperative imaging was described.

No limitations for publication date were made, which led to a wide selection of articles eligible for inclusion. The full texts of the included studies were assessed and studies were excluded if:

1. No criteria and/or measurements for syndesmotomic reduction were provided (eg, TF distance was mentioned to be used for assessing reduction however the maximum value was not provided),
2. Only normative values were provided,
3. The study was a review,
4. Reduction of the ankle instead of syndesmosis was performed,
5. No original data were reported (same cohort reported twice with no new data), or
6. The full text article was not available.

For the included studies, the following data were extracted: year of the study, modality used for the assessment of quality of reduction, criteria for assessing reduction, and if available, functional outcome. Among the studies included, some only referred to other included studies (original publications) when mentioning their threshold for anatomic reduction. We decided not to fully display these studies but rather to mention the citations in the tables under the column number of citations. For this reason, the number of included studies (n=52) does not match the studies that are shown in the tables (n=38).

## Results

The search was last updated on the August 8, 2018. In total, 2157 articles were found, of which 736 were duplicates; duplicates were removed (Fig. 1). A total of 1421 studies were screened for title and abstract after which 1311 studies were excluded. The remaining 110 studies were eligible for full-text analysis. Of these, 61 studies were excluded because of the following reasons:

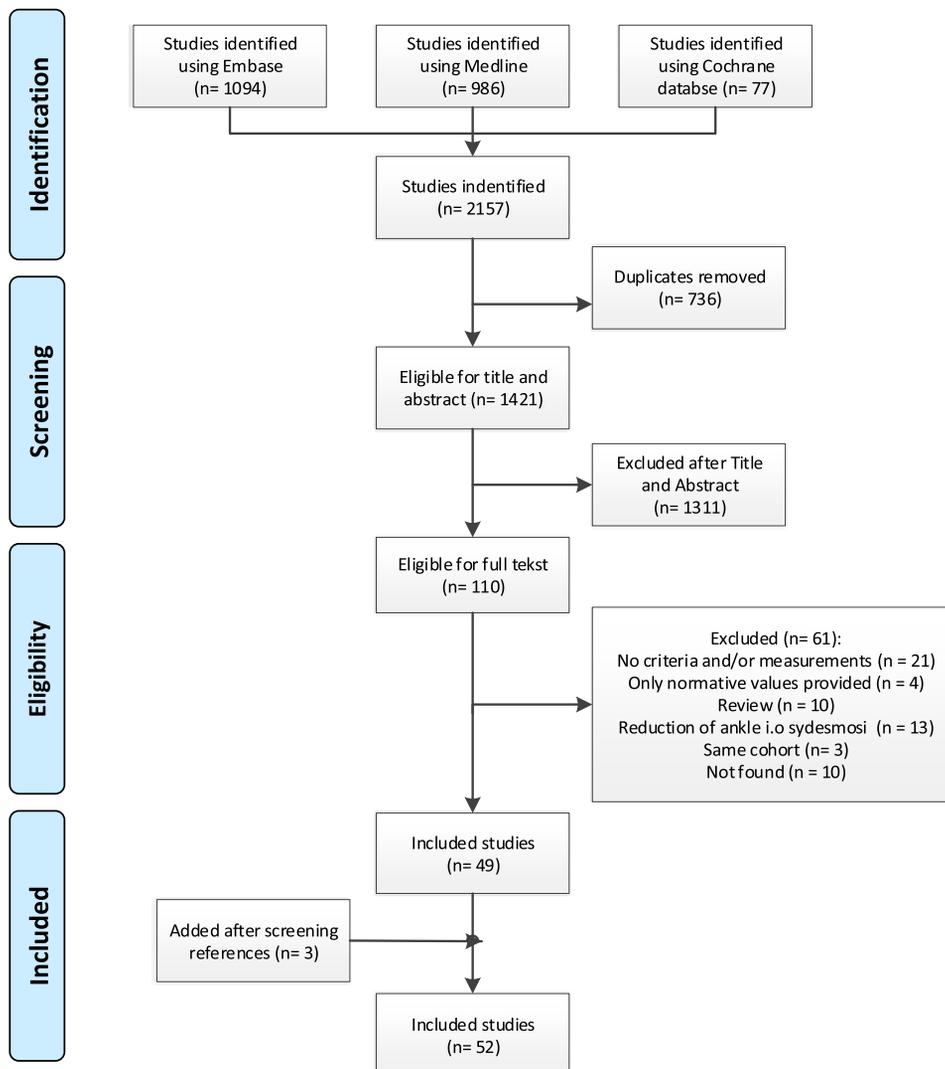
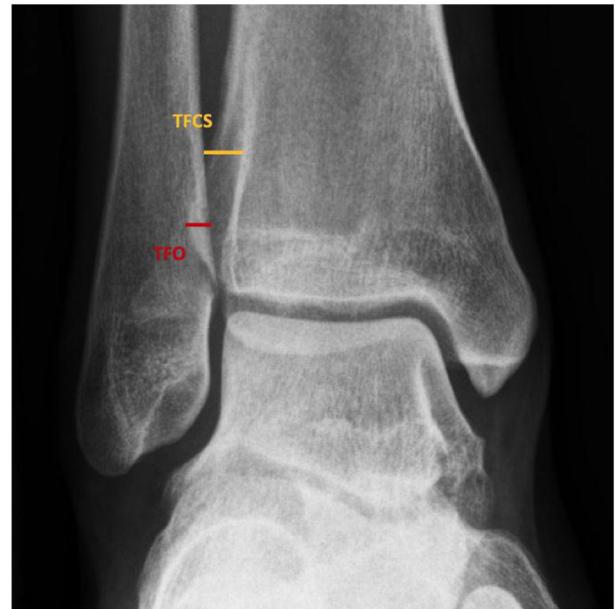


Fig. 1. Flowchart for the literature search according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2009 guidelines.

**Table 1**  
Original studies assessing reduction on plain radiographs

Year	TF Clear Space	Medial Clear Space	TF Overlap	AP Displacement Lateral View	Superior Clear Space	Lateral Clear Space	Talocrural Angle	Anterior Fibular Line Ratio	Posterior Fibular Line Distance	Shenton's Line	No. of Citations*
1983	•		•								4
1989	•		•								1
1995	•		•	•							1
2006	•		•								
2010	•	•	•								
2011	•	•	•	•			•				
2011	•	•	•								
2012	•	•	•								
2013	•	•	•								
2014	•	•	•	•							
2015	•	•	•								1
2015	•	•	•								
2017	•	•	•							•	
2017	•	•	•							•	
2017	•	•	•							•	
Total	9	8	7	3	2	1	1	1	1	1	

Abbreviations: AP, anteroposterior; TF, tibiofibular.  
\* Number of citations in the included studies.



**Fig. 2.** Measurements according to Harper et al (17) in anteroposterior view (weightbearing). TFCS, tibiofibular clear space; TFO, tibiofibular overlap.



**Fig. 3.** Measurements according to Harper et al (17) in mortise view (weightbearing). TFCS, tibiofibular clear space; TFO, tibiofibular overlap.

1. No criteria and/or measurements for syndesmotic reduction were provided (n = 21),
2. Only normative values were provided (n = 4),
3. The study was a review (n = 10),
4. Reduction of the ankle instead of syndesmosis was described (n = 13),
5. No original data were reported (n = 3), or
6. The full-text article was not available (n = 10).

Three studies were added after screening the references of the included studies. Fourteen original studies used plain radiographs for the assessment of quality of reduction, 19 used standard computed

**Table 2**  
Original studies assessing reduction on computed tomographic scans

Reference	Year	Contralateral Side	Anterior TF Distance	Posterior TF Distance	Fibular Rotation	AP Fibular Translation	TF Clear Space	TF Overlap	TF Line	Art. Gap >2 mm	Art. Step-off >2 mm	Syndesmotic Area	Distal TF Volumes	Fibular Length	No. of Citations*
Tang et al (31)	2003	•			•										2
Gardner et al (19)	2006		•	•											7
Vasarhelyi et al (32)	2006	•			•										2
Peiton et al (20)	2010		•	•											2
Mukhopadhyay et al (22)	2011	•	•	•	•	•									4
Dikos et al (33)	2012	•	•	•	•		•								1
Naqvi et al (23)	2012	•	•	•	•										1
Sagi et al (7)	2012	•			•										1
Berkes et al (34)	2013	•	•	•	•	•					•				1
Davidovitch et al (35)	2013		•	•	•	•									1
Nault et al (30)	2013		•	•	•	•									2
Miller et al (36)	2013				•										7
Gifford et al (37)	2014				•										1
Schottel et al (25)	2014		•	•											1
Kortekangas et al (38)	2015	•	•	•	•										1
Kocadal et al (39)	2016	•	•	•	•							•			1
Kotwal et al (40)	2016	•	•	•	•										1
Boszyk et al (14)	2017	•	•	•	•	•									1
Prior et al (41)	2017	•	•	•	•	•									1
Total		12	11	11	7	6	3	1	1	1	2	1	1		1

Abbreviations: AP, anteroposterior; Art., articular; TF, tibiofibular.  
\* Number of citations in included studies.

tomographic (CT) scans and 5 used (intraoperative) 3-dimensional (3D) CT scans.

*Postoperative plain radiographs*

An overview of the studies using plain radiographs for the assessment of quality of reduction is depicted in Table 1. In total, 10 different parameters were described. The TF clear space was the parameter included most frequently in criteria for assessing the reduction (9 of the included studies). The method by Harper et al (17) was cited the most times (n = 3). Measurements according to Harper et al (17) existed of:

1. A TF “clear space” on the anteroposterior and mortise views of less than approximately 6 mm;
2. TF overlap on the anteroposterior view of greater than approximately 6 mm or 42% of fibular width; and
3. TF overlap on the mortise view of > 1 mm (Figs. 2 and 3).

*CT Scans*

An overview of the studies using CT scans for the assessment of quality of reduction is depicted in Table 2. In total, 12 different parameters were described. Parameters used the most were anterior TF distance (n = 11), posterior TF distance, (n = 11) and fibular rotation (n = 7); in 12 studies the anatomy was compared with the noninjured contralateral side. The method by Gardner et al (19) and Nault et al (30) were cited the most (n = 7). Measurements from Gardner et al (19) contained the distance between the fibula and the anterior and posterior facets of the incisura; Nault et al (30) added fibular rotation, anterior posterior translation, and TF clear space to these measurements (19, 30) (Fig. 4). Differences between the anterior and posterior measurements of >2 mm were considered incongruous (19, 30).

*Three-Dimensional Reconstructions of Radiographs*

An overview of the studies using 3D reconstructions (in 3 planes—sagittal, coronal, and axial) for the assessment of quality of reduction are depicted in Table 3. In total, 6 parameters were described.

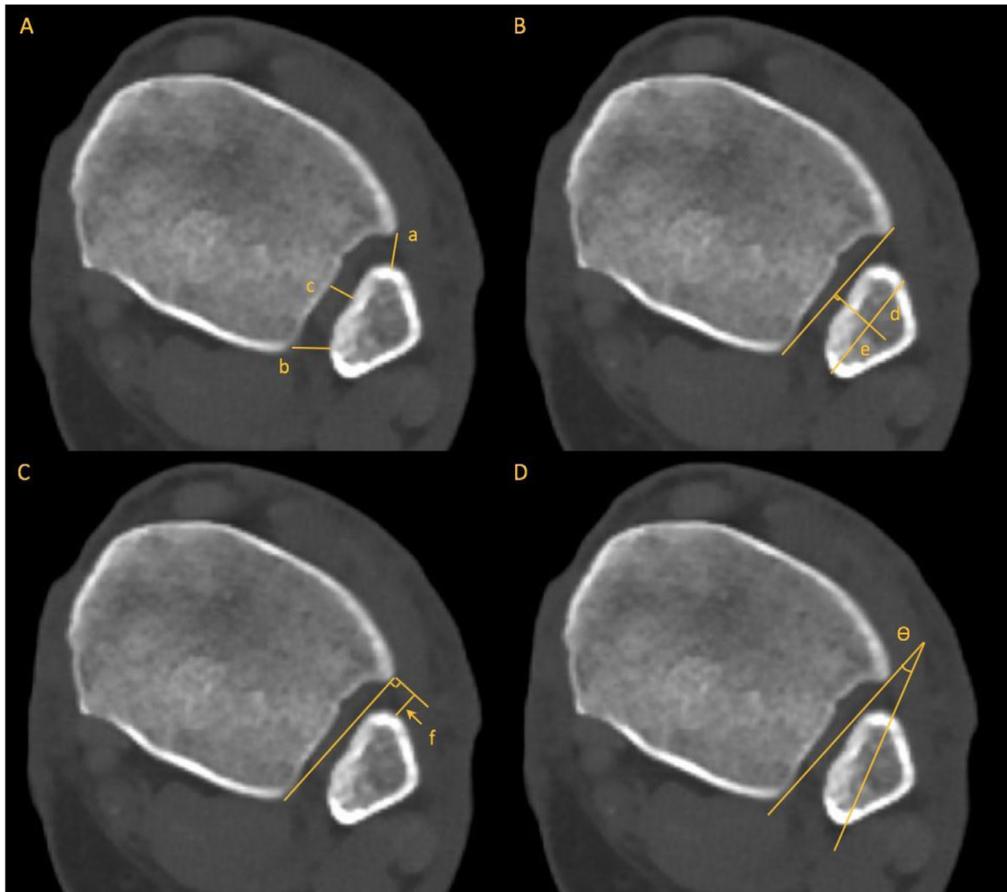
*Functional Outcome*

An overview of the studies using CT scans for the assessment of relation between functional outcome and anatomic versus nonanatomic reduction is depicted in Table 4. In total, 6 studies described a relation between functional outcomes and malreduction (7, 23, 34, 38, 40). Three of these studies found a significant relation between the quality of reduction and functional outcomes (7, 23, 34).

**Discussion**

The aim of the present study was to systematically review the literature regarding the various methods used for assessing the quality of distal TF syndesmotic reduction. Three modalities that are being used for this purpose were identified and included in this study, namely, plain radiography, CT scans, and 3D CT scans. In total, 52 studies were included and a total of 28 different parameters were identified (plain radiographs (49), CT scans (50), and 3D CT scans (15)). In addition, 6 studies investigated the relation between functional outcomes and malreduction.

The results of this study show that CT scanning was the most used modality (n = 19), followed by plain radiography (n = 14) and 3D CT scans (n = 5). TF clear space (n = 9) and medial clear space (n = 8) where the most used parameters for plain radiography. Anterior TF distance (n = 11) and posterior TF distance (n = 11) where the most frequently



**Fig. 4.** Axial computed tomography scan containing the measurements of Nault et al (30). (A) Anterior tibiofibular distance. (B) Posterior tibiofibular distance. (C) Distance between the tibia and the fibula in the middle of the incisura. (D) Distance between the anterior part of the fibula and the perpendicular. (E) Distance between the posterior part of the fibula and the perpendicular in line with the anterior measure. (F) The same perpendicular line is brought at the level of the most anterior point of the incisura. Distance between that line and the most anterior point of the fibula.  $\theta$ , angle between a line drawn between the anterior and posterior point of the incisura and a line drawn in the fibula representing its orientation (internal rotation being a negative angle).

used parameters for CT scanning. Fibular rotation (n = 2) was used the most times for 3D CT scans. Knops et al (42) evaluated 4 methods for measuring fibular rotation and recommended that the angle between the tangent of the anterior tibial surface and the bisection of the vertical midline of the fibula at the level of the incisura is most reliable.

Prior studies have noted that plain radiography is not sufficient for an accurate diagnosis of syndesmotom reduction (19, 49, 51, 52). Gardner et al (19) found that CT scans detected significantly more (52%) syndesmotom malreductions compared with standard postoperative radiographic measurements (24%). In addition, Ebraheim et al (49) showed that CT scanning is more sensitive in detecting minor degrees of syndesmotom injuries compared with plain radiography. Furthermore, Garner et al (53) showed that the intraobserver and interobserver

variability was low for plain radiographs in the assessment of ankle fracture reduction. This finding is conceivable because cutoff values of 1 to 2 mm are proposed, which may be very difficult to measure accurately on plain radiographs. Therefore, CT scanning is thought to be superior to plain radiography, although it has the disadvantage that in most hospitals this modality is not available intraoperatively. This barrier means that syndesmotom malreduction may only be detected postoperatively, demanding a reoperation.

Intraoperative 3D reconstructions of radiographs may offer a solution to this problem. A small number of studies suggest that 3D CT scanning is more accurate in detecting reduction of the syndesmotom compared with plain radiography. Franke et al (50) describe that intraoperative 3D scans altered the surgical outcome in 82 of 251 (32.7%)

**Table 3**  
Original studies assessing reduction on 3-dimensional reconstructions

Reference	Year	Fibular Rotation	Volume of Syndesmotom Space	TF Overlap	Position in TF Incisura	Medial and Lateral Clear Space	Trans-syndesmotom Angle	No. of Citations*
Marmor et al (21)	2011	•						
Knops et al (42)	2013	•						
Franke et al (43)	2014			•	•	•		
Schon et al (44)	2017		•					
Putnam et al (45)	2017						•	
Total		2	1	1	1	1	1	

Abbreviation: TF, tibiofibular.

\* Number of citations in included studies.

**Table 4**  
Functional outcome in patients with anatomic vs nonanatomic reduction

	Modality	Anatomical Reduction	Nonanatomic Reduction	P value
Berkes et al (34)	CT	77.3*	66.8*	.05
Kortekangas et al (38)	CT	85 <sup>†</sup>	69 <sup>†</sup>	NS
Sagi et al (7)	CT	46.3 <sup>‡</sup>	72.7 <sup>‡</sup>	.05
Kotwal et al (40)	CT	93.1 <sup>‡</sup>	88.4 <sup>‡</sup>	NS
Naqvi et al (23)	Radiographs, CT	NP <sup>§</sup>	NP <sup>§</sup>	.02
Cherney et al (46)	CT	62.6 <sup>‡</sup>	67.5 <sup>‡</sup>	NS <sup>§</sup>

Abbreviations: CT, computed tomographic scan; NP, not provided; NS, not significant.

\* Foot and Ankle Outcome Score subdomain symptoms.

<sup>†</sup> Olerud-Molander score.

<sup>‡</sup> American Orthopaedic Foot and Ankle Society hindfoot-ankle (47, 48)

<sup>§</sup> Three cutoff values for malreduction are described; the most liberal cutoff is depicted here.

ankles. Three-dimensional reconstructions of radiographs have proved to be most helpful in intraoperative recognition of inadequate reduction (54). They are, however, not widely available and therefore these results are of doubtful clinical relevance.

Twelve of the 19 studies performed a bilateral CT scan for direct comparison between the uninjured and surgically treated sides. This practice is of additive value in improving the accuracy of syndesmotom reduction because the anatomy may differ in each patient. To allow for an accurate comparison of the syndesmoses, all measurements were made at the level 1 cm proximal to the tibial plafond. Although not described by all authors, the use of a cast or fixation device may be used to improve the comparability with the uninjured contralateral side as both legs are in the same position. Recent studies found that there is an anatomic variation in the shape of the incisura fibularis (14, 15, 22, 55). Surprisingly, imaging of both ankles was performed in only 1 study that used plain radiography. Surgeons should be aware of possible variations and therefore both ankles should be visualized. In addition, Shah et al (56) showed that it is more effective to compare the syndesmosis with the uninjured ankle instead of comparing the syndesmosis with normative values based on the general population. Furthermore for adequate reduction, fibular length is essential (57).

There seems to be a negative relationship between functional outcomes and malreduction. Weening et al (8) found that the only significant predictor of functional outcome was reduction of the syndesmosis. The results of this study are in line with those of previous studies, suggesting a negative relation between malreduction and functional outcome. For example, Sagi et al (7) demonstrated significantly worse functional outcomes at a minimum of 2 years follow-up.

There are several limitations to our study. A large number of different parameters was used in the included studies with different cutoff values making interpretation of the results difficult and a planned meta-analysis impossible. In addition, only a few articles studied the relation between functional outcomes and reduction of the syndesmosis, which could provide more insight as to which parameters are clinically relevant. However, despite our appreciation of the limitations of our investigation, we believe that the results of this study could be useful. Especially in research as an unambiguous parameter regarding syndesmotom, (mal) reduction is mandatory for comparing different studies on this subject.

Although a meta-analysis was not possible, some recommendations based on the results can be made. We believe CT scanning is superior to plain radiographs and in case of doubtful reduction, a CT scan should be made. Furthermore, both ankles should be visualized in all cases to assess any possible anatomic variations. Criteria for reduction of the syndesmosis should include at least the

1. Position of the fibula in the incisura,
2. Fibular rotation, and
3. Fibular length.

We propose this parameter to be measured through anterior TF distance, posterior TF distance, fibular length, and fibular rotation all equaling  $\leq 2$  mm or  $<10^\circ$ , respectively (58), when compared with the uninjured contralateral side. By imaging the contralateral side, strict cutoff values are redundant; the anatomy of the syndesmosis on the injured side should approximate the uninjured side. This technique also has the advantage that it can be applied using all modalities.

In conclusion, our findings suggest that a CT scan is superior to plain radiography in the assessment of the quality of syndesmotom joint reduction. The criteria for adequate reduction should at least include the position of the fibula in the incisura, rotation of the fibula, and adequate fibular length. We propose this parameter to be measured through anterior TF distance, posterior TF distance, fibular rotation, and fibular length, all equaling or at least approaching the values of the uninjured contralateral side. Second, the findings of this study support the notion of a negative relation between malreduction and functional outcome.

### Supplementary Materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1053/j.jfas.2018.08.038>.

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