

Radiographic parameters of the normal ankle syndesmosis: Comparison between hindfoot alignment view and anteroposterior view

Jaehyung Lee², Ho Seong Lee¹, Ji Wan Kim¹,
Bum-Sik Lee¹ and Youngrak Choi¹ 

Abstract

Objective: To compare the parameters associated with the normal ankle syndesmosis between the hindfoot alignment view (HAV) and anteroposterior (AP) view and determine which view is more accurate for comparing the left and right ankles.

Methods: This study involved 61 subjects without syndesmosis injury who had radiographs of both ankles. The tibiofibular clear space (TFCS), tibiofibular overlap (TFO), and medial clear space (MCS) were measured in each view. Intraclass correlation coefficients were used to assess the agreement between the two ankles. Difference ratios for the measured parameters between the ankles were also compared.

Results: The agreement for TFCS showed wide disparity between the two ankles (AP view, 0.576; HAV, 0.858). The highest degree of agreement was seen for TFO (AP view, 0.733; HAV, 0.926). The agreement for MCS was low in both groups. The mean difference ratio for TFCS was also lower in the HAV group (9.9%) than in the AP view group (16.4%); a similar result was observed for TFO (16.4% vs. 25.8%).

Conclusions: For evaluation of the syndesmosis, use of the HAV showed increased accuracy and few measurement errors when comparing the left and right ankles relative to use of the AP view.

¹Department of Orthopedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Republic of Korea

²Department of Orthopaedic Surgery, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, Anyang-si, Gyeonggi-do, Republic of Korea

Corresponding author:

Youngtrak Choi, Department of Orthopedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88, Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Republic of Korea.

E-mail: jeanguy@hanmail.net



Keywords

Syndesmosis, hindfoot alignment view, anteroposterior view, ankle joint, radiography, accuracy

Date received: 8 March 2022; accepted: 19 April 2022

Introduction

Syndesmosis injuries can occur in isolation or, more commonly, in association with ankle fractures. If neglected or malreduced, syndesmosis injuries can cause chronic instability, which may progress to osteoarthritis (OA). Thus, increasing emphasis has been placed on the detection of syndesmosis injuries; however, radiographic diagnosis can be difficult in some instances, leading to misdiagnosis and neglect.

Radiographic parameters associated with the syndesmosis that can be measured on simple radiography include the tibiofibular clear space (TFCS), tibiofibular overlap (TFO), and medial clear space (MCS). These parameters can have a wide range of values among individual patients and may differ according to the degree of ankle rotation during radiographic examination. The use of cut-off values for these parameters in isolation for classifying normal and abnormal conditions is reportedly ineffective.¹⁻⁴ The current consensus is to use the contralateral ankle as the reference for comparison in identification of the presence of syndesmosis injury.⁵ A major pitfall of this approach is that the radiograph of the contralateral ankle is usually acquired separately; thus, the beam angle or degree of rotation may differ, potentially confounding the radiographic analysis.

Radiographs are usually taken in the hindfoot alignment view (HAV) when assessing hindfoot alignment.⁶⁻⁸ Various other radiographic views, such as the Saltzman, long axial, and Méary views, have also been utilized in the analysis of hindfoot alignment.⁹⁻¹¹ However, depending

on the angle of the radiographic beam, the HAV can be used to visualize not only heel alignment but also the ankle joint and syndesmosis. In addition, because images of both lower extremities are usually taken simultaneously, the HAV facilitates an intuitive comparison of both ankles. Previous studies have used the HAV to calculate the medial distal tibial angle and compare it with that calculated using images taken in the anteroposterior (AP) and mortise views.^{6,12} However, no studies have used the HAV to measure syndesmosis-related parameters or to compare such parameters with those measured in the AP view. In this study, under the premise that the radiological syndesmosis-related parameters have the same values in the left and right ankles in the healthy population, we assumed that the differences between the left and right ankle measurements are smaller when the measurements are made using the HAV (in which images of both ankles are taken symmetrically at the same time) than when they are made in the AP view (in which images of the ankles are usually taken separately).

In this study, we measured the parameters associated with the normal ankle syndesmosis in the AP view and HAV in subjects who showed no evidence of syndesmosis injury. We aimed to determine whether the AP view or HAV is more accurate in comparing the left and right ankles.

Patients and methods

The reporting of this study conforms to the STROBE guidelines.¹³

Patient selection

We retrospectively reviewed the medical charts of patients with radiographs of the right and left ankles taken in the weight-bearing AP view and HAV at our institution from March 2018 to May 2020. Patients with a history of hindfoot or ankle fracture, a history of hindfoot or ankle surgery, Kellgren–Lawrence grade ≥ 3 ankle OA, or active inflammatory arthritis were excluded. In total, 122 ankles of 61 subjects (27 men and 34 women) were included in this study. The most common diagnoses were flatfoot deformity, Kellgren–Lawrence grade ≤ 2 ankle OA, hallux valgus, plantar fasciitis, Achilles tendinopathy, cavus deformity, neuropathic pain, and heel or ankle pain of unknown etiology. The patients' mean age was 56.2 years (range, 19–82 years). This study was approved by the institutional review board of the authors' affiliated institutions. The need for informed consent was waived because of the retrospective nature of this study and the lack of identifiable information of the patients in the manuscript.

Radiographic technique

The X-ray beam settings were as follows: 10 mAs, 60 kV, and a focus distance of 100 cm for the AP view and 20 mAs, 70 kV, and a focus distance of 100 cm for the HAV.

For the AP view, the beam was angled parallel to the floor, while the film cassette was positioned perpendicular to the floor in the usual manner. The subjects were instructed to stand in an upright position with the second toe of the target ankle facing the front. The left and right ankle radiographs were taken on separate films.

For the HAV, instead of the classic Saltzman method, we used a modified, more clinically practical version of the

Saltzman method. The beam was angled at 15° to the floor, while the film cassette was positioned perpendicular to the floor (Figure 1). The subjects were instructed to distribute their weight evenly on both legs and stand in an upright position. The medial borders of both feet were placed in parallel positions to minimize rotation, and the second toes of both feet were aligned parallel to the X-ray beam.

All radiographs were digitally obtained from the picture archiving and communication system (PetaVision 2.0) of our institution.

Radiographic analysis

The TFCS, TFO, and MCS were measured in both the AP view and HAV (Figure 2).^{2,14} The TFCS was defined as the distance between the medial border of the fibula and the incisura fibularis, 10 mm proximal to the tibial plafond. The TFO was defined as the distance between the medial border of the fibula and the lateral border of the tibia, 10 mm proximal to the tibial plafond. The MCS was defined as the distance between the medial border of the talus and the lateral border of the medial malleolus, 5 mm inferior to the medial shoulder of the talus. All radiographic parameters were evaluated by two board-certified orthopedic surgeons. For the assessment of interobserver reliability, all parameters were evaluated separately for each image by each observer and compared. For the assessment of intraobserver reliability, the measurement process was repeated 4 weeks after the initial process and the results were compared.

Statistical analysis

Intraclass correlation coefficients (ICCs) were used to assess the agreement between the measured values for the left and right ankles of each subject. For each subject, the



Figure 1. Hindfoot alignment view: the modified version of the classic Saltzman view. The beam is angled at 15° to the floor, and the film cassette is placed perpendicular to the floor.

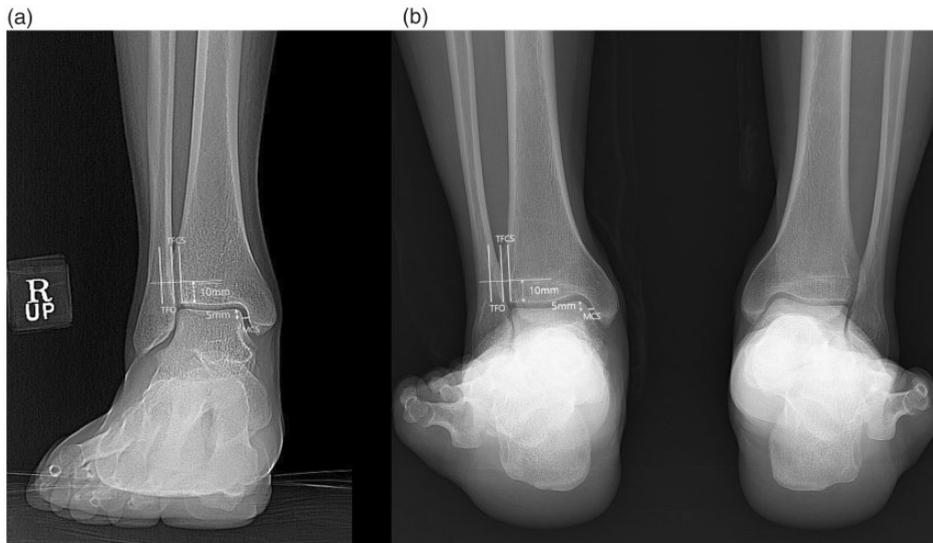


Figure 2. Measured radiographic parameters in the (a) anteroposterior view and (b) hindfoot alignment view. The parameters comprised the tibiofibular overlap (TFO), tibiofibular clear space (TFCS), and medial clear space (MCS).

differences in the measured values between the two ankles were calculated with regard to both the AP view and HAV, and the average difference was compared using a paired *t* test. To avoid any bias that may arise from the magnitude of the difference in values between the two views, a comparison was performed using the difference ratio for each group. The difference ratio was calculated as the difference between the left and right ankle values divided by the average value $[(Rt - Lt) / \{(Rt + Lt) / 2\}]$. In other words, a high difference ratio means that the difference between the left and right ankle values is large, regardless of the magnitude of the measurement values of both ankles.

Bland–Altman plots were used to quantify the agreement between the values of both ankles. A 95% interval of agreement was confirmed for the differences in the average TFCS, TFO, and MCS. ICCs were also used to evaluate the intraobserver and interobserver reliabilities with respect to each view. For all tests, a *P*-value of <0.05 was considered statistically significant. The collected data were analyzed using the IBM SPSS version 25 software (IBM Corp., Armonk, NY, USA).

Results

Comparison of measured values

The mean TFCS, TFO, and MCS values in the AP view and HAV are displayed in

Table 1. Several previous studies have suggested that the cut-off value of the TFCS in the AP view is 5 mm¹⁵ or 6 mm.^{16,17} In this study, the incidence rates of a TFCS of >5 mm in the AP view and HAV were 32.7% and 45.9%, respectively, and those of a TFCS of >6 mm were 9.8% and 18.9%, respectively.

Comparison of left and right ankles

The agreement between the measured parameters for the left and right ankles was evaluated using ICCs. All parameters showed higher agreement in the HAV group than in the AP view group (Table 2).

For the MCS, the agreement was low in both groups. For the TFCS, the agreement showed a wide disparity between the groups. The TFO showed the highest degree of agreement.

For the TFCS, the mean difference between the left and right ankles was

Table 2. Agreement in measurements between right and left ankles.

	AP view		HAV	
	ICC	95% CI	ICC	95% CI
TFCS	0.576	0.380–0.722	0.858	0.774–0.912
TFO	0.733	0.591–0.831	0.926	0.880–0.955
MCS	0.339	0.097–0.543	0.372	0.135–0.569

AP, anteroposterior; HAV, hindfoot alignment view; TFCS, tibiofibular clear space; TFO, tibiofibular overlap; MCS, medial clear space; ICC, intraclass correlation coefficient; CI, confidence interval.

Table 1. Measurements of radiological parameters.

	AP view		HAV	
	Mean (mm)	95% CI (mm)	Mean (mm)	95% CI (mm)
TFCS	4.51	4.26–4.82	5.14	4.85–5.43
TFO	5.96	5.36–6.57	4.68	4.20–5.18
MCS	2.47	2.27–2.68	2.19	1.94–2.41

AP, anteroposterior; HAV, hindfoot alignment view; CI, confidence interval; TFCS, tibiofibular clear space; TFO, tibiofibular overlap; MCS, medial clear space.

smaller in the HAV group than in the AP view group. For the TFO, the mean side-to-side difference was smaller in the HAV group than in the AP view group. Because the magnitude of the differences in the measured parameters differed between the two groups, a direct comparison of the mean difference may have led to statistical errors; thus, the mean difference was converted into a ratio. The mean difference ratio for the TFCS was found to be lower in the HAV group than in the AP group, with a similar result for the TFO. The mean difference ratio for the MCS was found to be lower in the AP group than in the HAV group (Table 3).

The Bland–Altman plots demonstrated that for the TFCS and TFO, the 95% intervals of agreement were much smaller in the HAV group than in the AP view group, indicating that the HAV group showed a smaller mean difference between the left and right ankles. The MCS showed similar agreement in both groups (Figure 3).

Intraobserver and interobserver reliability

The TFO showed high intraobserver and interobserver reliability in both the AP view and HAV groups. The TFCS showed good reliability, albeit less than that of the TFO, and showed no significant difference between the two groups. However, the MCS had relatively low reliability in both groups (Table 4).

Discussion

Radiographic parameters used to evaluate syndesmosis injuries should be measured in reference to the values for the contralateral ankle to overcome patient-specific variations.^{2,5,18} In the present study, we tested the hypothesis that HAV radiographs that are taken for both ankles in conjunction and in symmetrical positions can be advantageous in comparing the left and right ankles.

On the premise that the TFCS and TFO must be nearly identical for both ankles in a healthy individual, the ICCs for the measured values on both sides indicated higher agreement in the HAV than AP view group. In addition, the mean difference ratio between the two ankles was obtained, and the comparative analysis revealed that the difference for the TFCS and TFO was significantly smaller in the HAV group than in the AP view group.

Several previous studies have suggested that the radiological indicators related to the syndesmosis can vary depending on the degree of rotation of the ankle or hindfoot.^{2–4} Based on these reports, we assumed that the difference in the degree of rotation of the left and right ankles is more likely to be greater in the AP view, taking each ankle separately, than in the HAV, taking both ankles at once. The results of our study are consistent with this assumption.

Table 3. Difference in measurements between right and left ankles.

	Mean difference (Rt – Lt) (mm)			Mean difference ratio [(Rt – Lt) × 100/{(Rt + Lt)/2}] (%)		
	AP view	HAV	P value	AP view	HAV	P value
TFCS	0.73	0.49	0.011	16.4	9.9	0.003
TFO	1.39	0.57	<0.001	25.8	16.4	0.004
MCS	0.66	0.71	0.583	19.0	37.7	<0.001

Rt, right; Lt, left; AP, anteroposterior; HAV, hindfoot alignment view; TFCS, tibiofibular clear space; TFO, tibiofibular overlap; MCS, medial clear space.

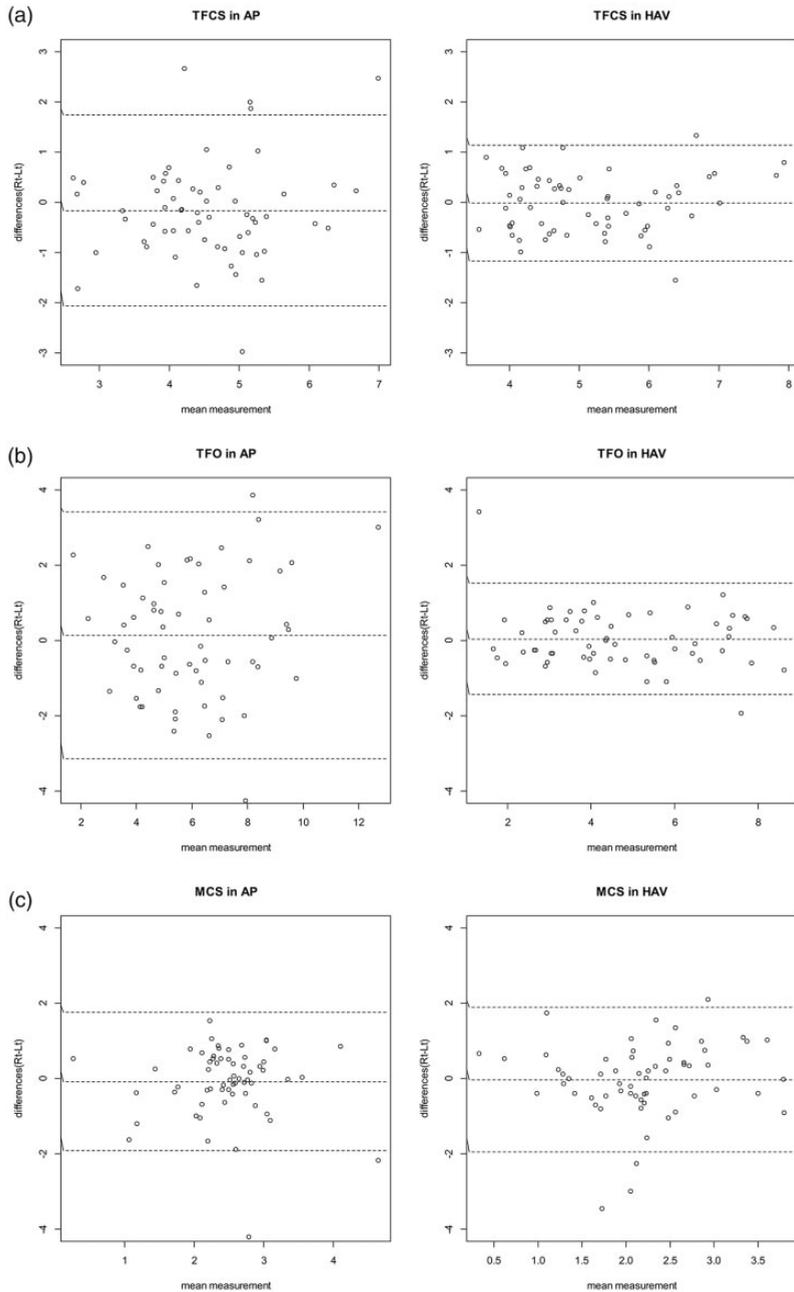


Figure 3. Bland–Altman plots of the differences in the measured values of both ankles. A 95% interval of agreement (dotted line) was confirmed for the differences in the average (a) tibiofibular clear space (TFCS), (b) tibiofibular overlap (TFO), and (c) medial clear space (MCS).

Table 4. Intraobserver and interobserver reliability.

	Intraobserver		Interobserver	
	AP view	HAV	AP view	HAV
TFCS	0.890	0.909	0.896	0.891
TFO	0.987	0.984	0.954	0.965
MCS	0.798	0.731	0.769	0.785

Data are presented as intraclass correlation coefficients. TFCS, tibiofibular clear space; TFO, tibiofibular overlap; MCS, medial clear space; AP, anteroposterior; HAV, hindfoot alignment view.

We reviewed the radiographs of both ankles of 61 healthy subjects taken in the weight-bearing AP view and HAV. Some previous studies have suggested a TFCS cut-off value of 5 mm¹⁵ or 6 mm,^{16,17} but our study showed many deviations from those values. This demonstrates the great variability in the radiographic measurements of healthy people, a finding similar to other recent studies.^{5,19,20} Additionally, the mean TFCS was smaller in the AP view than in the HAV, whereas the mean TFO was larger in the AP view than in the HAV. The cause of these differences may be that in the AP view, the X-ray beam is transmitted from the front to the back of the ankle and directed to the center of the ankle, whereas in the HAV, the beam is transmitted from the back of the ankle to the front and approaches the midpoint between the two ankles. It is reasonable to consider checking the difference between the two ankles in each image and to compare this difference between the two views. However, there may be a variation in the degree of rotation between the two views, which would have affected the aforementioned results.¹⁻³

Our study also demonstrated that unlike the TFCS and TFO, the MCS had relatively low reliability and showed low agreement in the comparison of the left and right ankles. Other studies have suggested that minor

deviations in the X-ray beam angle or ankle rotation can cause MCS measurement errors.^{21,22} Metitiri et al.²³ asserted that the parallax effects make it difficult to reliably identify the true margins of the clear space and that the curved shape of the medial border of the talus distorts the true and reproducible margin of the MCS. Our results are consistent with these assertions. In addition, when the articular surface of the medial malleolus was not parallel to the beam, both the anterior and posterior borders became visible, making measurement difficult and adversely impacting reliability. Therefore, using the MCS alone to determine syndesmosis injury may not be appropriate.

In this study, the widely used Saltzman method was not adopted for radiographs in the HAV; instead, the X-ray beam was angled at 15° to the floor, with the cassette placed perpendicular to the floor. However, the image obtained with this protocol was nearly identical to that obtained using the Saltzman method, providing clear visualization of the ankle joint and heel alignment. In actuality, the Saltzman method requires the cassette to be perpendicular to the beam, and making such adjustments while taking each HAV radiograph is time-consuming and may hinder consistency. In contrast, the method used in this study requires no adjustment of the cassette, decreasing the burden on the radiographic technician and ensuring consistency.

This study has two main limitations. First, despite the wide range of patient ages, the sample size was relatively small; this makes it difficult to generalize the results to an entire adult population. An additional study involving more subjects or a specific disease group is necessary to provide more insight into this topic. Second, this study was conducted in patients whose radiographs were taken in the weight-bearing AP view and HAV. Therefore, our results are difficult to apply

to patients with acute trauma who cannot undergo radiography in the weight-bearing view. Our results are only applicable to patients with subacute or chronic injury. Further investigation comparing radiological parameters in non-weight-bearing and weight-bearing views will help to clarify these concerns.

Conclusion

Relative to the AP view, the HAV is more accurate and can decrease measurement errors when comparing the left and right ankles. Evaluation of the syndesmosis in the HAV has high intraobserver and interobserver reliability. In addition to the assessment of heel alignment, the HAV facilitates intuitive visualization of both ankles and remarkable side-to-side comparison for evaluation of the syndesmosis.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

ORCID iD

Youngrak Choi  <https://orcid.org/0000-0002-8037-2650>

References

1. Anand Prakash A. Syndesmotic stability: is there a radiological normal?—a systematic review. *Foot Ankle Surg* 2018; 24: 174–184.
2. Beumer A, Van Hemert WL, Niesing R, et al. Radiographic measurement of the distal tibiofibular syndesmosis has limited use. *Clin Orthop Relat Res* 2004; 423: 227–234.
3. Krähenbühl N, Akkaya M, Dodd AE, et al. Impact of the rotational position of the hindfoot on measurements assessing the integrity of the distal tibio-fibular syndesmosis. *Foot Ankle Surg* 2020; 26: 810–817.
4. Pneumaticos SG, Noble PC, Chatziioannou SN, et al. The effects of rotation on radiographic evaluation of the tibiofibular syndesmosis. *Foot Ankle Int* 2002; 23: 107–111.
5. Shah AS, Kadakia AR, Tan GJ, et al. Radiographic evaluation of the normal distal tibiofibular syndesmosis. *Foot Ankle Int* 2012; 33: 870–876.
6. Barg A, Amendola RL, Henninger HB, et al. Influence of ankle position and radiographic projection angle on measurement of supramalleolar alignment on the anteroposterior and hindfoot alignment views. *Foot Ankle Int* 2015; 36: 1352–1361.
7. Choi JY, Lee HI, Kim JH, et al. Radiographic measurements on hindfoot alignment view in 1128 asymptomatic subjects. *Foot Ankle Surg* 2021; 27: 366–370.
8. Buber N, Zanetti M, Frigg A, et al. Assessment of hindfoot alignment using MRI and standing hindfoot alignment radiographs (Saltzman view). *Skeletal Radiol* 2018; 47: 19–24.
9. Neri T, Barthelemy R and Tourne Y. Radiologic analysis of hindfoot alignment: comparison of Meary, long axial, and hindfoot alignment views. *Orthop Traumatol Surg Res* 2017; 103: 1211–1216.
10. Dagneaux L, Moroney P and Maestro M. Reliability of hindfoot alignment measurements from standard radiographs using the methods of Meary and Saltzman. *Foot Ankle Surg* 2019; 25: 237–241.
11. Arena CB, Sripanich Y, Leake R, et al. Assessment of hindfoot alignment comparing weightbearing radiography to weight-bearing computed tomography. *Foot Ankle Int* 2021; 42: 1482–1490.
12. Barg A, Harris MD, Henninger HB, et al. Medial distal tibial angle: comparison between weightbearing mortise view and hindfoot alignment view. *Foot Ankle Int* 2012; 33: 655–661.
13. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007; 147: 573–577.

14. Gennis E, Koenig S, Rodericks D, et al. The fate of the fixed syndesmosis over time. *Foot Ankle Int* 2015; 36: 1202–1208.
15. Krahenbuhl N, Weinberg MW, Davidson NP, et al. Imaging in syndesmotic injury: a systematic literature review. *Skeletal Radiol* 2018; 47: 631–648.
16. Ebraheim NA, Lu J, Yang H, et al. Radiographic and CT evaluation of tibiofibular syndesmotic diastasis: a cadaver study. *Foot Ankle Int* 1997; 18: 693–698.
17. Magan A, Golano P, Maffulli N, et al. Evaluation and management of injuries of the tibiofibular syndesmosis. *Br Med Bull* 2014; 111: 101–115.
18. Kubik JF, Rollick NC, Bear J, et al. Assessment of malreduction standards for the syndesmosis in bilateral CT scans of uninjured ankles. *Bone Joint J* 2021; 103: 178–183.
19. Rammelt S and Ogruba P. An update on the evaluation and treatment of syndesmotic injuries. *Eur J Trauma Emerg Surg* 2015; 41: 601–614.
20. Amin A, Janney C, Sheu C, et al. Weight-bearing radiographic analysis of the tibiofibular syndesmosis. *Foot Ankle Spec* 2019; 12: 211–217.
21. Murphy JM, Kadakia AR and Irwin TA. Variability in radiographic medial clear space measurement of the normal weight-bearing ankle. *Foot Ankle Int* 2012; 33: 956–963.
22. Ashraf A, Murphree J, Wait E, et al. Gravity stress radiographs and the effect of ankle position on deltoid ligament integrity and medial clear space measurements. *J Orthop Trauma* 2017; 31: 270–274.
23. Metitiri O, Ghorbanhoseini M, Zurakowski D, et al. Accuracy and measurement error of the medial clear space of the ankle. *Foot Ankle Int* 2017; 38: 443–451.