Article

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle International®
2017, Vol. 38(12) 1380–1386

DOI: 10.1177/1071100717730328
journals.sagepub.com/home/fai

A Radiographic Dye Method for Intraoperative Evaluation of Syndesmotic Injuries

Murad Pepe, MD[1], Onur Kocadal, MD[1], Zafer Gunes, MD[1], Emre Calisal, MD[2], Kubilay Ceritoglu, MD[1], and Cem Nuri Aktekin, MD[3]

Abstract

Background: The Chertsey test has been recently defined as an intraoperative test for the detection of the syndesmotic injuries by the application of intra-articular contrast. However, no study has investigated the reliability and comparative analysis of the Chertsey test. The purpose of this study was to explore the diagnostic accuracy of the Chertsey test in predicting syndesmosis instability of the injured ankle, with correlation to preoperative computed tomography (CT) findings.
Methods: A total of 39 patients who were operated on due to the unilateral ankle fracture and had no complaint on the contralateral ankle joint were included in the study. An intraoperative Chertsey test was performed on all ankle fractures and bilateral ankle CT was obtained preoperatively. Ankles were classified as Chertsey +, Chertsey –, and contralateral control group. The morphology categorization, width, and volume of the syndesmotic region were measured on axial images of the CT. Mann-Whitney *U* test was used to compare the data. Intraobserver and interobserver agreements were accessed by calculating the intraclass correlation coefficient (ICC) for radiologic parameters and the Chertsey test.
Results: The Chertsey test was positive in 13 (33.3%) of 39 ankle fractures. Patients with a positive Chertsey test showed a significant increase in syndesmotic width and volume compared with Chertsey – and control group. However, there was no significant difference between Chertsey – and the control group. All the ICC values were excellent for both radiologic measurements and test.
Conclusion: The Chertsey test is a reliable and useful test that can be used intraoperatively in the diagnosis of syndesmotic injuries.
Level of Evidence: III, comparative series.

Keywords: syndesmosis, ankle fracture, computed tomography, Chertsey test

Ankle syndesmosis injuries can cause posttraumatic arthritis, chronic instability, and ankle pain if not treated properly.[26,28] Preoperative and intraoperative methods are used for the diagnosis of syndesmosis injury. Methods include radiologic assessments, stress tests, and diagnostic ankle arthroscopy. However, the reliability of these methods remains controversial.[29] Although conventional radiographs are traditionally the most commonly used preoperative method, computed tomography (CT) is superior in evaluating syndesmotic diastasis.[4,14,21] Three-dimensional volume rendering of the spiral CT data found more accurate than axial CT images in even 1 mm diastasis of the tibiofibular syndesmosis.[24] Authors assessed the syndesmotic injury based on magnetic resonance imaging (MRI) and magnetic resonance arthrography (MRA) and found these tests to be quite sensitive in the diagnosis of diastasis and ligament injury.[15,16,27] However, high cost and availability limit the use of these methods.[20]

For intraoperative assessment, stress tests are commonly used to detect syndesmotic injury. Some surgeons prefer ankle arthroscopy, but the technique is invasive and requires surgical experience.[7,12,20,23] Recently, Boyd et al[1] found a new intraoperative assessment for the syndesmosis injury called the Chertsey test. The test includes an ankle arthrogram by contrast dye injection, and if a syndesmotic injury occurs, the radio-opaque contrast collects in the syndesmotic

[1]Ankara Training and Research Hospital, Orthopaedics and Traumatology, Ankara, Turkey
[2]Department of Orthopaedics and Traumatology, Amasya University, Amasya, Turkey
[3]Department of Orthopaedics and Traumatology, Ankara Yildirim Beyazit University, Ankara, Turkey

Corresponding Author:
Murad Pepe, MD, Ankara Training and Research Hospital, Orthopaedics and Traumatology, Ankara, Altindag 06340, Turkey.
Email: dr_muradpepe@hotmail.com

area. If there is no syndesmotic disruption, contrast dye collects only in the ankle joint. They mentioned that this test is safe, simple, and inexpensive. The test not only demonstrates the syndesmosis injury but also confirms the accurate reduction of the fibula. To our knowledge, there is no study about the reliability of the Chertsey test and correlation with the preoperative assessment methods. The purpose of this current study was to compare the intraoperative Chertsey test with the preoperative CT measurements in the diagnosis of syndesmotic injuries and analyze the reliability of these methods.

Methods

The study was conducted between July 2016 and February 2017 in patients who were operated on because of a unilateral ankle fracture and who had no complaints on the contralateral ankle joint. An intraoperative Chertsey test was performed to assess for a syndesmotic diastasis, and preoperative bilateral ankle CT images were obtained. The fixation of the ankle fractures was done in agreement with Arbeitsgemeinschaft für Osteosynthesefragen (AO) trauma fracture fixation principles. Syndesmotic fixation was performed using a transsyndesmotic 4.5-mm cancellous screw or a suture button device. All syndesmotic fixation decisions were made using the intraoperative Chertsey test. Patients who had an open or severely dislocated ankle fracture and/or previous surgery or fracture history of the contralateral ankle joint were excluded. Ankles were categorized as Chertsey + (syndesmosis unstable), Chertsey – (syndesmosis stable), and control (contralateral healthy side) groups. The local institutional review board approved the current study.

A total of 39 patients with 78 ankles were included in this study. The mean age of the patients was 44.6 years (range, 21-74 years). There were 22 (56.4%) men and 17 (43.6%) women. Of the 39 injured ankles, there were 19 (48.7%) lateral malleolus, 5 (12.8%) medial malleolus, 7 (17.9%) bimalleolar, and 8 (20.5%) trimalleolar fractures.

Imaging Technique and Evaluation

Radiologic evaluations were performed using preoperative bilateral ankle CT. We obtained the CT images with an Optima CT540 scanner machine (General Electric, Milwaukee, WI) with a 1.0-mm slice thickness. The morphology categorization, width, and volume analysis of the syndesmosis were measured on axial images of CT. Syndesmosis morphology was categorized as concave or shallow according to the depth of the incisura fibularis. The fibular incisura was described as shallow when the depth was less than 4 mm and concave when it was 4 mm or more.[6,25] Anterior (aTFD), middle (mTFD), posterior (pTFD), and maximal (maxTFD) tibiofibular distances were obtained from axial CT images at 10 mm proximal to the tibial plafond as described in previous studies.[5,25,29] Axial CT images were also used for the evaluation of the distal syndesmotic space volume. To standardize the measurements, surgeons determined the regions starting from the tibial plafond to 2 cm proximal. Syndesmosis space margins were outlined by a pencil tool following 20 axial CT images. Then volume was computed automatically by a program in cm^3 (Figure 1). All radiologic measurements were performed using Horos (Version 2.1.1 for Mac; Annapolis, MD) software on the injured and contralateral limbs.

Intraoperative Assessment

The intraoperative Chertsey test was applied to the injured ankle before fracture fixation on the operating table. A 20-gauge needle was inserted into the lateral aspect of the ankle joint and 2 to 4 mL radio-opaque contrast injected.[1] Anteroposterior (AP) and lateral radiographs were obtained by the image intensifier. If the contrast dye was seen tracking up to the syndesmotic space, the test was determined positive and syndesmotic fixation was performed. To ensure the anatomic reduction of syndesmotic diastasis, the surgeon repeated the test after fixation. If no contrast dye extravasation was seen in the syndesmotic area, the fixation was considered successful (Figure 2).

Statistical Analysis

The statistical analysis was performed using SPSS (version 20.0 for Mac; SPSS, Inc, an IBM Company, Chicago, IL) software. The distribution between the groups was assessed by the Kolmogorov-Smirnov test. Radiologic findings did not follow a normal distribution. Hence, the nonparametric Mann-Whitney *U* test was used to compare the data.

We analyzed the intraobserver and interobserver reliability for both methods. First, second and third authors measured the TFDs and volume of the syndesmotic area in the 2-week interval with Horos software on a computer. The Chertsey test images were printed from an image intensifier and evaluated by the same authors with the same interval. Both agreements were calculated by the intraclass correlation coefficient (ICC) 2-way mixed method on absolute agreement, and values were adopted by Fleiss criteria (0.75 to 1.00 indicates excellent reliability; 0.60 to 0.74, good reliability; 0.40 to 0.59, fair reliability; <0.40, poor reliability).[19]

Power analyses were performed by the G*power 3.1 (Erdfelder, Faul, & Buchner, Düsseldorf, Germany) statistical analysis program. The allocation ratio, α error probability, effect size *d* value, and power of the study (1 – β) were 1, 0.05, 0.7, and 0.9, respectively. The required total sample size was 72; thus, 78 ankles were included in the study.

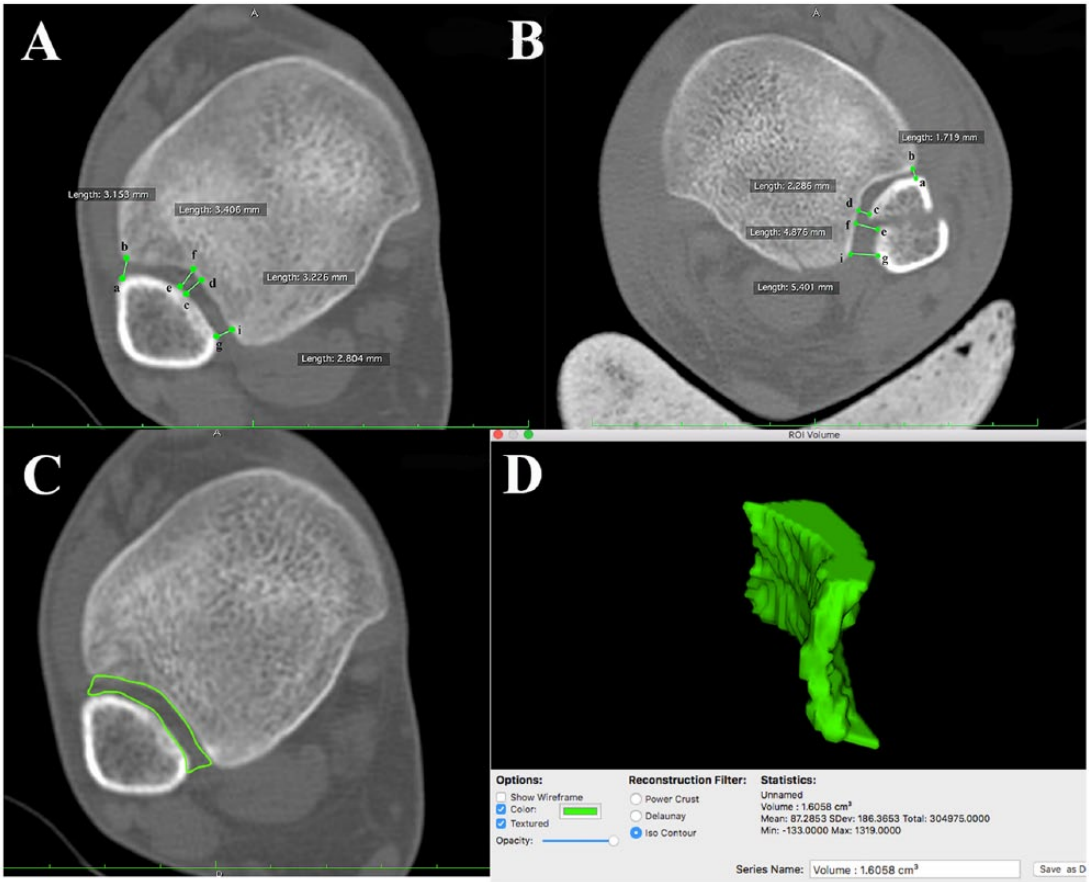

Figure 1. Measurement of (a-b) anterior, (c-d) middle, (e-f) maximal and (g-i) posterior tibiofibular distances in the (A) normal and the (B) fractured ankles. (C) To calculate the volume of the syndesmotic joint; the margin of the syndesmotic area was drawn on axial CT images. (D) Then, the volume was computed automatically by the program.

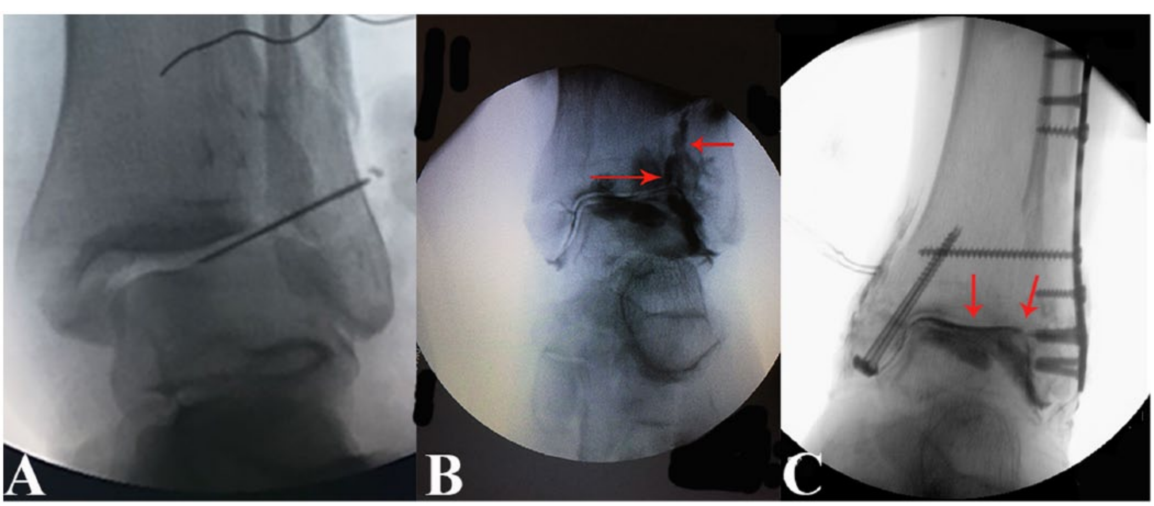

Figure 2. (A) A gauge needle insertion into the lateral aspect of the ankle joint and radio-opaque injection . (B) Contrast extravasation to the syndesmotic area demonstrates a positive Chertsey test. (C) Confirming accurate reduction by the contrast injection after fixation.

Table 1. Characteristics of Patients in Chertsey + and – Groups.[a]

Characteristic	Chertsey + Group (n = 13)	Chertsey – Group (n = 26)	*P* Value[b]
Age, mean ± SD, y	40.3 ± 15.5	46.5 ± 15.3	.409
Sex			.361
Male	6 (46.2)	16 (61.5)	
Female	7 (53.8)	10 (38.5)	
Morphology			.631
Concave	7 (53.8)	14 (53.8)	
Shallow	6 (46.2)	12 (46.2)	
Diagnosis			.551
Lateral malleol fracture	5 (38.5)	14 (53.8)	
Medial malleol fracture	1 (7.7)	4 (15.4)	
Bimalleol fracture	3 (23)	4 (15.4)	
Trimalleol fracture	4 (30.8)	4 (15.4)	

[a]Values are presented as number (%) unless otherwise indicated.
[b]χ^2 Test for categorical variables.

Table 2. Comparison of Distal Tibiofibular Distance Measurements and Syndesmotic Volumes in Patients in the Chertsey +, Chertsey –, and Control Groups.

Characteristic	Chertsey + Group (n = 13)	Chertsey – Group (n = 26)	Control Group (n = 39)	*P* Value
aTFD, mm	4.2 ± 4.2	2.4 ± 1.2	2.5 ± 1.0	<.05[a] <.05[b] .715[c]
mTFD, mm	5.1 ± 3.1	3.0 ± 1.2	2.8 ± 1.2	<.05[a] <.05[b] .720[c]
pTFD, mm	5.0 ± 1.7	3.7 ± 1.0	3.3 ± 0.9	<.05[a] <.05[b] .201[c]
maxTFD, mm	6.3 ± 3.7	4.3 ± 1.1	4.1 ± 1.2	<.05[a] <.05[b] .531[c]
Volume, cm^3	2.2 ± 0.9	1.6 ± 0.4	1.5 ± 0.4	<.05[a] <.05[b] .467[c]

Abbreviations: aTFD, anterior tibiofibular distance; maxTFD, maximal tibiofibular distance; mTFD, middle tibiofibular distance; pTFD, posterior tibiofibular distance.
[a]Independent *t* test between Chertsey + and – groups.
[b]Independent *t* test between Chertsey + and control groups.
[c]Independent *t* test between Chertsey – and control groups.

Results

The incisura fibularis morphology was shallow in 18 (46.2%) and concave in 21 (53.8%) patients. The Chertsey test was positive in 13 (33.3%) of 39 injured ankles (Table 1). The mean aTFD, mTFD, pTFD, and maxTFD were 4.2, 5.1, 5.0, and 6.3 mm in the Chertsey + group; 2.4, 3.0, 3.7, and 4.3 mm in the Chertsey – group; and 2.5, 2.8, 3.3, and 4.1 mm in the control group. Distance measurement differences were statistically significant between the Chertsey + and – groups, as well as the Chertsey + and control groups ($P < .05$). However, there was no significant difference between the Chertsey – and control groups. The mean syndesmotic region volume was 2.2 cm^3 in the Chertsey + group, 1.6 cm^3 in the Chertsey – group, and 1.5 cm^3 in the control group. Also, volume differences between the Chertsey + and – groups, as well as the Chertsey + and control groups, were statistically significant, but no significant difference was found between the Chertsey – and control groups (Table 2).

Both the intraobserver and interobserver ICCs were excellent in the Chertsey test, TFDs, and volume measurements for all 3 observers (Table 3). However, intraobserver ICC and the interobserver ICC were better in the Chertsey

Table 3. Intraclass Correlation Coefficients in the Intraoperative Chertsey Test and Preoperative Radiological Measurements.

Characteristic	Chertsey Test	aTFD	mTFD	pTFD	maxTFD	Volume
Intraobserver 1	0.972	0.876	0.921	0.879	0.915	0.898
Intraobserver 2	0.950	0.914	0.884	0.890	0.901	0.863
Intraobserver 3	0.964	0.904	0.871	0.888	0.879	0.849
Overall intraobserver	0.962	0.898	0.892	0.885	0.898	0.870
Interobserver	0.947	0.823	0.812	0.802	0.831	0.810

Abbreviations: aTFD, anterior tibiofibular distance; maxTFD, maximal tibiofibular distance; mTFD, middle tibiofibular distance; pTFD, posterior tibiofibular distance.

test than in the distal tibiofibular distance and volume measurement.

Discussion

An intact syndesmosis is essential for a properly functioning ankle joint. The widening of the tibiofibular syndesmosis may cause chronic ankle instability, pain, and arthritis in the long term. Structures that contribute the most to the diastasis are syndesmotic ligaments. The main ligaments that stabilize the syndesmotic joint include the anterior inferior tibiofibular ligament (AITFL), interosseous tibiofibular ligament (ITFL), and posterior inferior tibiofibular ligament (PITFL).[3] Ruptures of these ligaments can lead to syndesmotic diastasis. Even 1 mm of diastasis may decrease the syndesmotic contact area by 42%[18] and increase the syndesmotic joint space volume by 43%.[24]

The diagnosis of syndesmosis injury is evaluated by preoperative and intraoperative methods. Conventional radiography, CT, MRI, and MRA are imaging methods that help to diagnose in the preoperative period. Static and/or stress AP, lateral, and mortise ankle radiographs are used frequently.[17,21] Tibiofibular clear space, tibiofibular overlap, and medial clear space are parameters used to assess the integrity of the syndesmosis in conventional radiographs.[4,9,11] However, it is not reliable to detect the syndesmosis injury with these parameters alone.[8,21] Ebraheim et al[5] mentioned that 4 mm of widening could be reliably predicted by plain radiography and showed that CT was much more sensitive in minor diastasis. Taser et al[24] found that tibiofibular syndesmotic injuries could detect even 1 mm of diastasis by volume rendering with 3-dimensional CT. Some authors support MRI to clarify the syndesmotic complex injuries.[2,8,13] However, it is expensive and there could be availability problems, and experience is necessary to visualize injured ligaments.[16] Muratlı et al[15] found that MRA could make an important contribution to the diagnosis. However, it should not be forgotten that it is a more invasive method than MRI. More commonly, intraoperative lateral (bone hook) and external rotation stress tests are used to evaluate the syndesmotic stability.[20,30] Syndesmotic injuries correlate with increases in the measurements on stress fluoroscopy. However, it is controversial whether the surgeon can detect small amounts of instability.[10] It is possible to diagnose syndesmosis injury with ankle arthroscopy,[16,22] but it is invasive and often not readily available.

Tibiofibular distance measurements on axial CT images predict syndesmotic instability. Yeung et al[29] found significantly larger tibiofibular distances in ankle fractures with unstable syndesmoses than a stable group. They found that the means of aTFD, mTFD, pTFD, and maxTFD in unstable syndesmosis patients were 4.9 ± 3.7 mm, 5.3 ± 2.4 mm, 5.3 ± 1.8 mm, and 7.2 ± 2.96 mm, respectively. They were 4.2 ± 4.2 mm, 5.1 ± 3.1 mm, 5.0 ± 1.7 mm, and 6.3 ± 3.7 mm in our Chertsey + (syndesmosis unstable) group, respectively. While Yeung et al[29] compared these distances between stable and unstable syndesmosis with ankle fractures, we compared between Chertsey + (syndesmosis unstable), Chertsey – (syndesmosis stable) groups with ankle fractures, and contralateral normal ankles. In the Chertsey + group, we found the increased tibiofibular distances at the significant level compared with the Chertsey – and control groups and found no significant difference between the Chertsey – and control groups (Table 1).

Studies that measured normal syndesmotic volume in the literature reported mean values between 1.02 and 1.59 cm^3.[11,24] We found the mean volume of the control group was 1.5 ± 0.4 cm^3. In a cadaver study, it was reported that a 0- to 1-mm syndesmotic joint diastasis increased the volume 43%, as well as 20% with each 1-mm diastasis from 1 to 3 mm.[24] In our study, the Chertsey + group had significantly increased volume (2.2 ± 0.9 cm^3) compared with the Chertsey – and control groups (Table 2).

We also performed a reliability analysis for the intraoperative Chertsey test and preoperative radiological parameters and found excellent reliability in all techniques (Table 3). However, intraobserver and interobserver ICCs were higher in the Chertsey test than the preoperative CT measurements.

There are some limitations of our study. Our sample size is relatively small. However, the patient sample size is comparable to similar previous diagnostic studies.[15,21] The second limitation of the study was the absence of postoperative

CT images to demonstrate anatomic reduction after fixation. However, if the radio-opaque dye does not migrate into the syndesmotic area, it shows that there is an anatomic reduction in the syndesmotic joint.

Conclusion

Our study showed that the intraoperative Chertsey test was similar to preoperative tomography findings in the diagnosis of syndesmotic injuries. We believe this test can take the place of other methods when cost and radiation effects of the tomography are considered.

Editor's Note

The authors should be congratulated for a study evaluating a radiographic dye method of assessing syndesmotic integrity. It would have been interesting if they could have correlated the degree of instability necessary to have a positive test since this is ultimately what we are aiming to correct with surgical repair. Perhaps a future study could evaluate this aspect of the test.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Boyd RPR, Nawaz SZ, Khaleel A. A new assessment for syndesmosis injury: the ‘Chertsey test’. *Injury*. 2016;47(6):1293-1296.
2. Campbell SE, Warner M. MR imaging of ankle inversion injuries. *Magn Reson Imaging Clin North Am*. 2008;16(1):1-18.
3. Clanton TO, Williams BT, Backus JD, et al. Biomechanical analysis of the individual ligament contributions to syndesmotic stability. *Foot Ankle Int*. 2017;38(1):66-75.
4. Dikos GD, Heisler J, Choplin RH, Weber TG. Normal tibiofibular relationships at the syndesmosis on axial CT imaging. *J Orthop Trauma*. 2012;26(7):433-438.
5. Ebraheim NA, Lu J, Yang H, Mekhail AO, Yeasting RA. Radiographic and CT evaluation of tibiofibular syndesmotic diastasis: a cadaver study. *Foot Ankle Int*. 1997;18(11):693-698.
6. Ebraheim NA, Lu J, Yang H, Rollins J. The fibular incisure of the tibia on CT scan: a cadaver study. *Foot Ankle Int*. 1998;19(5):318-321.
7. Feller R, Borenstein T, Fantry AJ, et al. Arthroscopic quantification of syndesmotic instability in a cadaveric model. *Arthroscopy*. 2017;33(2):436-444.
8. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreduction of the tibiofibular syndesmosis in ankle fractures. *Foot Ankle Int*. 2006;27(10):788-792.
9. Harper MC. An anatomic and radiographic investigation of the tibiofibular clear space. *Foot Ankle Int*. 1993;14(8):455-458.
10. Jenkinson RJ, Sanders DW, Macleod MD, Domonkos A, Lydestadt J. Intraoperative diagnosis of syndesmosis injuries in external rotation ankle fractures. *J Orthop Trauma*. 2005;19(9):604-609.
11. Kocadal O, Yucel M, Pepe M, Aksahin E, Aktekin CN. Evaluation of reduction accuracy of suture-button and screw fixation techniques for syndesmotic injuries. *Foot Ankle Int*. 2016: 37(12):1317-1325.
12. Lui TH, Ip K, Chow HT. Comparison of radiologic and arthroscopic diagnoses of distal tibiofibular syndesmosis disruption in acute ankle fracture. *Arthroscopy*. 2005; 21(11):1370-1377.
13. Muhle C, Frank LR, Rand T, et al. Tibiofibular syndesmosis: high-resolution MRI using a local gradient coil. *J Comput Assist Tomogr*. 1998;22(6):938-944.
14. Mukhopadhyay S, Metcalfe A, Guha AR, et al. Malreduction of syndesmosis—are we considering the anatomical variation? *Injury*. 2011;42(10):1073-1076.
15. Muratlı HH, Biçimoğlu A, Çelebi L, Boyacıgil S, Damgacı L, Tabak AY. Magnetic resonance arthrographic evaluation of syndesmotic diastasis in ankle fractures. *Arch Orthop Trauma Surg*. 2005;125(4):222-227.
16. Oae K, Takao M, Naito K, et al. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis 1. *Radiology*. 2003;227(1):155-161.
17. Pneumaticos SG, Noble PC, Chatziioannou SN, Trevino SG. The effects of rotation on radiographic evaluation of the tibiofibular syndesmosis. *Foot Ankle Int*. 2002;23(2):107-111.
18. Ramsey PL, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Jt Surg Am*. 1976;58(3):356-357.
19. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull*. 1979;86(2):420.
20. Stoffel K, Wysocki D, Baddour E, Nicholls R, Yates P. Comparison of two intraoperative assessment methods for injuries to the ankle syndesmosis. *J Bone Jt Surg Am*. 2009;91(11):2646-2652.
21. Summers HD, Sinclair MK, Stover MD. A reliable method for intraoperative evaluation of syndesmotic reduction. *J Orthop Trauma*. 2013;27(4):196-200.
22. Takao M, Ochi M, Naito K, et al. Arthroscopic diagnosis of tibiofibular syndesmosis disruption. *Arthroscopy*. 2001;17(8):836-843.
23. Takao M, Ochi M, Oae K, Naito K, Uchio Y. Diagnosis of a tear of the tibiofibular syndesmosis. *Bone Jt J*. 2003;85(3):324-329.
24. Taser F, Shafiq Q, Ebraheim NA. Three-dimensional volume rendering of tibiofibular joint space and quantitative analysis of change in volume due to tibiofibular syndesmosis diastases. *Skeletal Radiol*. 2006;35(12):935-941.
25. Taşer F, Toker S, Kılınçoğlu V. Evaluation of morphometric characteristics of the fibular incisura on dry bones. *Jt Dis Rel Surg*. 2009;20(1):52-58.
26. van den Bekerom MPJ, de Leeuw PAJ, van Dijk CN. Delayed operative treatment of syndesmotic instability: current concepts review. *Injury*. 2009;40(11):1137-1142.

27. Vogl TJ, Hochmuth K, Diebold T, et al. Magnetic resonance imaging in the diagnosis of acute injured distal tibiofibular syndesmosis. *Invest Radiol*. 1997;32(7):401-409.
28. Willmott HJS, Singh B, David LA. Outcome and complications of treatment of ankle diastasis with tightrope fixation. *Injury*. 2009;40(11):1204-1206.
29. Yeung TW, Chan CYG, Chan WCS, Yeung YN, Yuen MK. Can pre-operative axial CT imaging predict syndesmosis instability in patients sustaining ankle fractures? Seven years' experience in a tertiary trauma center. *Skeletal Radiol*. 2015;44(6):823-829.
30. Zalavras C, Thordarson D. Ankle syndesmotic injury. *J Am Acad Orthop Surg*. 2007;15(6):330-339.