Original Article

Intraoperative Chertsey Test, is it a Reliable Alternative to Computed Tomography Scan for Diagnosing Syndesmotic Injuries of the Ankle?

Abstract

Background: The present study aims to evaluate the diagnostic exactitude of the intraoperative Chertsey test in tibiofibular syndesmotic injuries in patients with malleolar fractures, in comparison with a computed tomography (CT) scan. **Materials and Methods:** In this study, patients with malleolar fractures operated between 2018 and 2020 were examined. Thirty-nine patients were enrolled in the study. A three-dimensional preoperative CT scan was obtained. The opposite unfractured ankle was also scanned and considered as the control group. The Chertsey test was performed during the operation to assess the syndesmosis injury. Then, patients were partitioned into two distinct groups, considering the condition of their ankle, namely the Chertsey positive (unstable syndesmosis) group and the Chertsey negative (stable syndesmosis) group. **Results:** The outcomes of the present survey illustrated that the Chertsey test was positive in 16 patients (41.03%) and negative in 23 patients (59.07%). The median of all CT scan parameters (anterior tibiofibular distances (TFD), middle TFD, posterior TFD, and maximal TFD and volume) before surgery in the group of patients with a positive Chertsey test was significantly higher, measured against the unfractured control group ($P < 0.001$ for all parameters). Furthermore, a comparison of CT scan parameters and syndesmosis space volume before surgery between the two groups of patients with positive and negative Chertsey test results showed that the measurement of parameters in Chertsey-positive patients was significantly higher than the Chertsey-negative patients ($P < 0.001$). **Conclusion:** Chertsey test could be used to diagnose syndesmosis injuries in patients with malleolar fractures due to its high importance in the outcome of patients.

Keywords: *Ankle, chertsey test, computed tomography scan, malleolar fractures, syndesmosis*

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Introduction

In unstable fractures about the ankle joint with tibiofibular syndesmotic injuries, to reduce the potential risk of posttraumatic osteoarthritis, anatomic open reduction and internal osteosynthesis of the fracture site and re-establishment of the syndesmosis seem to be crucial.[1,2] Patients suffering from tibiofibular syndesmosis diastasis may experience severe and progressive pain years after the initial injury, often accompanied by postactivity swelling, which has a significant burden on patients' ability to do activities of daily living and quality of life.[3] Statistically, patients with the aforementioned symptoms constitute 22%–60% of patients that have had tibiofibular syndesmosis injury.[4] Standard surgical treatment for rotational ankle fractures includes evaluation of syndesmosis after osteosynthesis of the fractured malleolus and if the syndesmosis is disrupted, it should be reduced and fixed.[5]

A spectrum of methods including preoperative and intraoperative ones is utilized to evaluate syndesmosis injuries. These methods include but are not limited to radiological surveys, diagnostic ankle arthroscopy, and stress tests. However, the credibility of these methods remains contentious.[6] Measurement of two parameters, namely the tibiofibular clear space and tibiofibular overlap (TFO) in a conventional roentgenogram is the typical method of assessment, but they are plagued by the fact that only a single side of the complex ankle joint structure is shown.[7] Furthermore, fractures around the tibia and fibula may lead to an assortment of clinical signs and symptoms that convolute classical radiographic study. Another category of presumably more authentic dynamic test tools is stress test during the surgery, two

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of which are an external rotation test or a hook test.[8,9] However, these methods also have imperfections, as they require some sort of anesthesia and preclude presurgical data from being presented. Another diagnostic method is magnetic resonance imaging (MRI), which is less utilized due to its high cost and problems with patients that have previous metallic implants.[8]

Computed tomography (CT) scan is demonstrated to be practical in the assessment of ankle fracture morphology and tibiofibular syndesmotic disruptions.[9,10] CT scan provides the plenty of information about fracture patterns without much time and effort by creating a clear image of the bones and surrounding anatomical structures.[11,12] Similarly, recently, a method proposed by Boyd *et al*.[13] is the Chertsey test, which is an ankle arthrogram performed by injecting a small amount of a contrast medium into the ankle joint. In the presence of syndesmosis rupture, the accumulation of this contrast in the area of rupture during surgery becomes evident on fluoroscopic images, and in the absence of rupture, all the contrast accumulates in the ankle joint.

In light of the significance of the proper diagnosis of syndesmosis injury and its importance in improving patients' functional outcomes after fracture treatment and the diversity of available options, we decided to determine the specificity and accuracy of the Chertsey test compared to CT scan in ankle fractures.

Materials and Methods

Patients selection

This experimental case − control study is conducted between February 2018 and September 2020 in Imam Hossein University Hospital, Tehran, Iran. Fifty-two patients who were diagnosed with different types of malleolar fractures were studied. Initially, the objectives, nature, and process of the study were explained to the patients, and a form of written consent approved by the ethics committee of Shahid Beheshti University of Medical Sciences was received from all patients who entered the study. Individuals were also reassured that they could leave the study at any stage of the research that they were reluctant to continue to collaborate; also, their participation in the research would not interfere with their treatment.

The inclusion criteria were patient satisfaction, patients with a unilateral malleolar fracture in one of the subtypes of Lauge-Hansen classification who required surgery, and individuals with skeletal maturity and no pain or any clinical signs of trauma to the opposite ankle. The exclusion criteria were patient dissatisfaction with the study, patients avoiding follow-up sessions, open fractures, pilon fractures, concurrent calcaneus or talus fractures, and severe dislocations, which were caused in the recent incident or the patient's previous history. Finally, out of all 52 patients, 39 patients with malleolar fracture met the introductory criteria and entered the survey, and the variables of age, sex, morphology, and type of fracture in the patients were examined.

Procedure

In this study, a preoperative evaluation was performed by a three-dimensional CT scan of both ankles in axial, coronal, and sagittal cuts with a thickness of 1 mm. Morphological shape, volume, and width of syndesmosis were analyzed in axial CT scan images. Based on the size of the fibularis incisura on CT images, the morphology of syndesmosis was divided into "shallow" and "concave" groups. An incisural depth of <4 mm was considered shallow and more than 4 mm depth was considered concave. Anterior tibiofibular distances (ATFDs), middle tibiofibular distances (MTFDs), posterior tibiofibular distances (PTFDs), and maximal (MAX TFD) tibiofibular distances were measured on axial cuts 10 mm proximal to the tibial plafond. Furthermore, the volume of syndesmosis space was calculated by computer PACS software (OEM manufacturers India) and reported in milliliters.

An intraoperative Chertsey test was carried out to evaluate the syndesmosis injury and based on the results of this test, the condition of patients' ankles was divided into two groups: Chertsey positive (unstable syndesmosis) and Chertsey negative (stable syndesmosis). The opposite unfractured ankle was considered as the control group. Chertsey test was performed on the affected ankle before fracture osteosynthesis and on the radiolucent operating table. An 18G syringe containing 2–4 ml of water-soluble radiopaque contrast was injected from the lateral surface of the joint under image intensification, and after 3 min, the anteroposterior radiograph of the ankle joint was obtained using a C-arm. If the contrast path was spread in the tibiofibular syndesmosis area, the test was considered positive and syndesmosis reduction and fixation were done. In order to assure the quality of reduction and fixation, upon the completion of the procedure the test was repeated by the surgeon, and it was considered favorable if the contrast was removed from the tibiofibular syndesmosis area [Figure 1].

Osteosynthesis of ankle fractures was performed in accordance with Orthopaedic Trauma Association standard principles. Furthermore, in the Chertsey-positive group, fixation of syndesmosis was performed by a 3.5 mm trans-syndesmotic screw or by TightRope® XP Implant System (Arthrex Inc. Naples FL). The decision for the fixation method was based on the surgeon's preference.

Data analysis

Statistical analysis was conducted using the SPSS software version 22 (SPSS Inc. Chicago IL, USA) and after analysis of the demographics, type of morphology, and fracture type with Smirnov–Kolmogorov test, comparison of the above-mentioned distances between the groups was performed using the *t*-test. By virtue of the significant heterogeneity between the groups, the receiver operating characteristic curve (ROC) was plotted for the obtained values, and by determining the cutoff level, the parameters of sensitivity, specificity, positive, and negative predictive values (NPV) were obtained. $P < 0.05$ was considered statistically significant.

Results

Of 39 patients, 18 (46.2%) were female and 21 (53.8%) were male. The mean age of patients was 35.85 ± 11.52 years, the youngest patient being 20 years old and the oldest 68 years old. The most common type of fracture among patients was lateral malleolus (LM), which was observed in 19 patients (48.72%). Nine patients (23.08%) were bi-malleolar (BM), seven patients (17.95%) were tri-malleolar (TM), and 4 patients (10.26%) were MM (medial malleolus). The result of the intraoperative Chertsey test was positive in 16 patients (41.03 ٪) and negative in 23 patients (59.07%). Of these patients, 10 men (47.6%) and 6 women (33.3%) tested positive in Chertsey results [Table 1]. Although a positive test result was more common among men, no statistically significant difference was inspected between men and women, in terms of the Chertsey test results ($P = 0.366$).

Furthermore, ten patients (43.5%) with concave morphology and six patients (37.5%) with shallow morphology had positive test results. No statistically significant relationship was observed between syndesmotic morphology and the Chertsey test results ($P = 0.709$). The positive result of the Chertsey test was significantly more frequent in patients with TM (100%) and BM (55.6%) fractures than patients with LM (21.1%) and MM (0%) fractures ($P < 0.001$).

Notably, all parameters of the preoperative CT scan in the group of patients with a positive Chertsey test were significantly higher than their controls (the healthy opposite ankle) ($P < 0.001$ for all parameters) [Table 2].

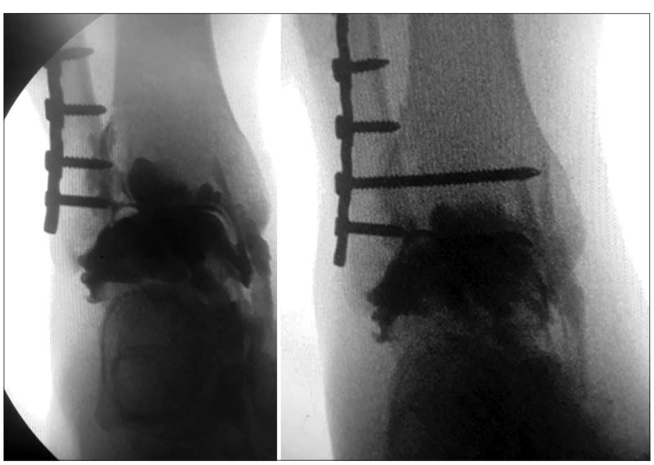

Figure 1: Intraoperative Chertsey test demonstrating the contrast medium spread into the tibiofibular syndesmosis that was removed after screw fixation

Among the patients with a negative test result, the median AFFD parameter for case and control groups was 2.40 mm and 2.30 mm, respectively, this difference was statistically significant ($P = 0.037$). Furthermore, the median MAX TFD was 4.20 mm among the patients with negative test results and 4.10 mm in their control counterparts, which showed a statistically significant difference ($P = 0.005$). However, there was no statistically significant difference in the distribution of MTFD ($P = 0.846$), PTFD ($P = 0.419$) and syndesmotic volume ($P = 0.224$) [Table 2].

Moreover, comparing the parameters of preoperative CT scan and syndesmotic volume between the two groups of patients with positive and negative Chertsey test results, demonstrated these parameters were significantly higher in patients with positive test results than the patients with negative results.($P < 0.001$ for all parameters and volume) [Figure 2].

The area under the ROC was obtained for all parameters, with a confidence interval of 95% (0.910–1) [Figure 3]. The cutoff points for each of the parameters were obtained according to the Yuden criterion; the cutoff point was 2.7 for ATFD, 3.1 for MTFD, 3.6 for PTFD, 4.5 for MAX TFD, and 2 for volume. The sensitivity of each of these cutting points was obtained 100% (79.4%–100%), specificity was 100% (85.2%–100%), positive predictive value (PPV) was 100% (79.4%–100%), and NPV was 100% (85.2%–100%) [Table 3].

Discussion

We herein compared a considerably simple intraoperative test and preoperative CT imaging in syndesmotic injuries of patients with ankle fractures. Syndesmotic ligaments are believed to be the preeminent anatomic structures that affect the tibiofibular joint diastasis. The instability of

Table 1: Description and comparison of basic characteristics of patients based on the Chertsey test results

Variable	The chertsey test results frequency (%)		*P*
	Negative	Positive	
Age (mean±SD)	33.57±10.98	39.13±11.84	0.128
Gender			
Male	11 (52.4)	10 (47.6)	0.366
Female	12 (66.7)	6 (33.3)	
Morphology			
Concave	13 (56.5)	10 (43.5)	0.709
Shallow	10 (62.5)	6 (37.5)	
Type of fracture			
BM	4 (44.4)	5 (55.6)	<0.001
LM	15 (78.9)	4 (21.1)	
MM	4 (100)	0	
TM	0	7 (100)	

BM: Bi-malleolar, LM: Lateral malleolus, MM: Medial malleolus, TM: Tri-malleolar, SD: Standard deviation

Table 2: Correlation of the parameters of preoperative computed tomography scan in patients with positive and negative Chertsey test results and the control group

Variable	Positive test		Control (positive)		*P*	Negative test		Control (negative)		*P*
	Median	Interquartile range	Median	Interquartile range		Median	Interquartile range	Median	Interquartile range	
ATFD	4.25	4.03-4.30	2.25	2.13-2.58	<0.001	2.40	2.20-2.60	2.40	2.20-2.60	0.037
MTFD	5.05	5.05-5.10	2.70	2.60-2.88	<0.001	2.80	2.70-2.90	2.80	2.70-2.90	0.846
PTFD	5.25	5.10-5.58	3.20	3-3.30	<0.001	3.30	3.10-3.40	3.30	3.10-3.40	0.419
MAX TFD	6.40	6.30-6.50	4	4-4.10	<0.001	4.20	4.10-4.30	4.20	4.10-4.30	0.005
Volume	2.50	2.40-2.58	1.50	1.40-1.50	<0.001	1.60	1.40-1.70	1.60	1.40-1.70	0.224

TFD: Tibiofibular distances, ATFD: Anterior TFD, MTFD: Middle TFD, PTFD: Posterior TFD, MAX: Maximal

Table 3: Cut-off points based on Yuden criterion for computed tomography scan parameters and preoperative volume and diagnostic values corresponding to cut-off points

Variable	Cut-off point	95% CI			
		Sensitivity	Specificity	PPV	NPV
Anterior	<2.7	100 (79.4-100)	100 (85.2-100)	100 (79.4-100)	100 (85.2-100)
Middle	<3.1	100 (79.4-100)	100 (85.2-100)	100 (79.4-100)	100 (85.2-100)
Posterior	<3.6	100 (79.4-100)	100 (85.2-100)	100 (79.4-100)	100 (85.2-100)
MAX	<4.5	100 (79.4-100)	100 (85.2-100)	100 (79.4-100)	100 (85.2-100)
Volume	<2	100 (79.4-100)	100 (85.2-100)	100 (79.4-100)	100 (85.2-100)

CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value, MAX: Maximal

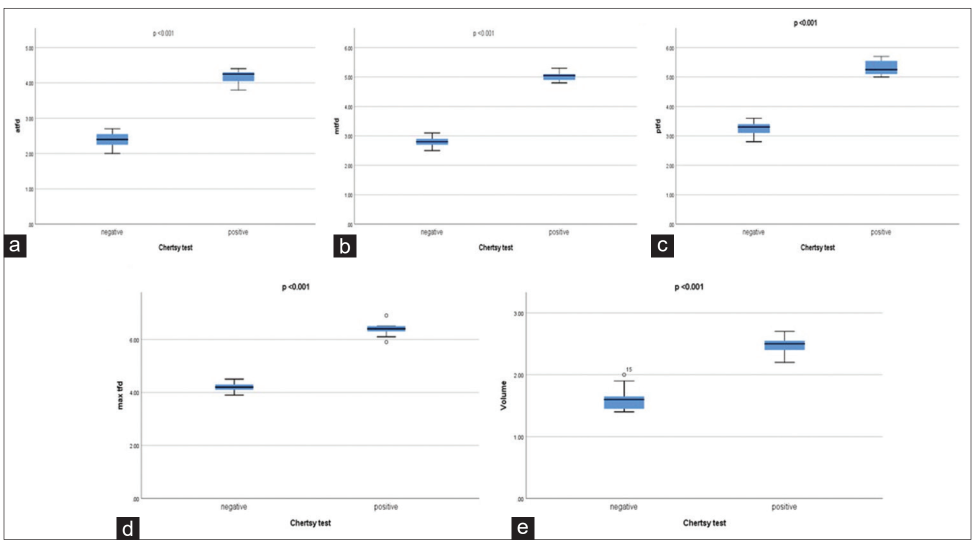

Figure 2: Comparison of anterior tibiofibular distances (a), Middle tibiofibular distances (b), Posterior tibiofibular distances (c), Maximal tibiofibular distances (d), and volume (e) parameters of patients based on the Chertsey test results

tibiofibular syndesmosis could lead to incapacitating long-term symptoms such as pain, ankle instability, and finally posttraumatic arthritis.[14,15] Taser *et al*. reported that a diastasis as low as 1 mm in tibiofibular syndesmosis may diminish the surface of contact area up to 42% and concurrently expand the volume of syndesmotic space up to 43%.[16] Distinctive preoperative and intraoperative approaches could be employed in the diagnosis of tibiofibular syndesmotic injuries. Some of these methods include plain radiography, CT scan, MRI, and magnetic resonance arthrography that assist with preoperative diagnosis. Intraoperative (C-Arm) stress orthogonal and internal oblique (mortise) X-rays of the ankle joint are also commonly utilized.[8,17,18]

In the current survey, the accuracy of the Chertsey test was evaluated, compared to the preoperative CT scan. The results showed that all parameters that were measured before the surgery, including ATFD, PTFD, MTFD, MAX TFD, and the volume of syndesmotic space in the axial CT scan, in patients whose Chertsey test was positive during surgery, were significantly different, in comparison with the group of patients with negative Chertsey test results. Furthermore, there were significant differences between the group of patients with positive Chertsey test and the healthy

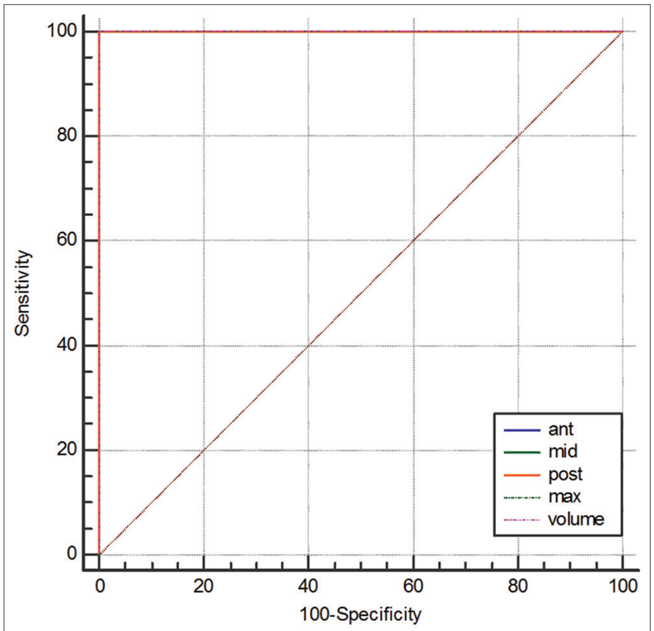

Figure 3: Operating characteristic curve of the different tibiofibular distance positions and volume obtained from the preoperative computed tomography scan

control group (healthy unfractured ankle). In addition, the ROC was used to determine the sensitivity, specificity, PPV, and NPV of each parameter by calculating the cutoff point and the obtained results were: ATFD >2.7 mm, MTFD >3.1 mm, PTFD >3.6 mm, MAX TFD >4.5 mm, and volume >2 mm^3. It is remarkably indicated that the sensitivity, specificity, positive predictive value, and NPV of each of these parameters were 100%.

Syndesmosis was previously defined only as of the ligament between the fibula and tibia, but consecutive studies have shown that other ligaments, such as anterior inferior tibiofibular ligament and posterior inferior tibiofibular ligament, are also involved in its structure.[19] Conventionally, the parameters utilized to determine the integrity of the syndesmosis include TFO, tibiofibular space, and exclusive internal space on a plain ankle roentgenogram.[20,21]

Ebraheim *et al*. concluded that a 4-mm space is the threshold to be detected by simple radiography means and also noted that using CT images results in a much precise diagnosis of partial syndesmotic diastasis.[22] Although obtaining quantitative measurements of CT scan may be impaired by some amount of interobserver and intraobserver discrepancy, it can reveal more descriptive information and spatial position than conventional radiographs. Since ankle fractures can lead to different patterns of disintegration of anatomical structures, plain radiography may not be sufficient to provide an extensive comprehension of the structure and probable injuries. These benefits have led to the use of CT scans as one of the worthwhile techniques for the diagnosis, and follow-up of ankle fractures.[7,23] The veracity of the abovementioned diagnostic parameters remains argumentative. Several studies have used various techniques for optimal diagnosis because there are so many alterations in measurements and differences between imaging and postoperative examinations of syndesmosis injuries. Measurement of the distance between tibia and fibula on axial cut CT scan images predicts syndesmotic inconstancy.[24-26] In 2016, Boyd *et al*. examined the Chertsey diagnostic test and found that this method could be very helpful in the diagnosis of syndesmosis injury intraoperatively. They stated that this test shows both an accurate evaluation of the syndesmosis injury and, if necessary, can assess the extent of fibular reduction.[13] Pepe *et al*.[27] in a study comparing the diagnostic value of preoperative CT scan and intraoperative Chertsey test stated that the dye injection test was positive in 13 out of 39 cases (33.3%) of ankle fractures. In their study, patients categorized as Chertsey positive demonstrated a noteworthy increment in the width and volume of the syndesmosis in comparison to the control group which is consistent with the present study results. They generally concluded that the Chertsey test is a decisive and advantageous test that can easily be performed during surgery to diagnose syndesmosis injuries.[27] Yeung *et al*. in a study of ankle fractures revealed that the mean ATFD, MTFD, PTFD, and MAXTFD in Chertsey positive group were 4.9 ± 3.7 mm, 5.3 ± 2.4 mm, 5.3 ± 1.8 mm, and 7.2 ± 2.96 mm, respectively, and in the Chertsey negative group were 4.2 ± 4.2 mm, 5.1 ± 3.1 mm, 5.0 ± 1.7 mm, and 6.3 ± 3.7 mm, respectively.[6]

It has been concluded that the Chertsey test only shows if there is an obvious abnormality in the syndesmosis; however, as with other assessments, it does not predict the extent of damage to the syndesmosis. There must also be a complete disruption of the interosseous ligaments to produce a positive test, and there may be partial damage to the syndesmosis that results in persistent clinical symptoms but leading to a negative Chertsey test.[13] Finally, one of the limitations of the present study was the small sample size; it is recommended to increase the sample size and add CT images that are taken after the anatomical reduction or fixation, in future studies.

Conclusion

According to the results, the Chertsey test can help diagnose syndesmosis injuries in patients with different types of ankle fractures, due to its high sensitivity and specificity. In addition, this method is easily done during the surgery and is less expensive than a CT scan and the patients are exposed to much less radiation.

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Conflicts of interest

There are no conflicts of interest.

References

1. Bäcker HC, Vosseller JT. Fibula fracture: Plate versus nail fixation. Clin Orthop Surg 2020;12:529-34.
2. Ray R, Koohnejad N, Clement ND, Keenan GF. Ankle fractures with syndesmotic stabilisation are associated with a high rate of secondary osteoarthritis. Foot Ankle Surg 2019;25:180-5.
3. El-Rosasy M, Ali T. Realignment-lengthening osteotomy for malunited distal fibular fracture. Int Orthop 2013;37:1285-90.
4. van Vlijmen N, Denk K, van Kampen A, Jaarsma RL. Long-term results after ankle syndesmosis injuries. Orthopedics 2015;38:e1001-6.
5. Pfirrmann CW, Notzli HP, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology 2005;235:969-76.
6. Yeung TW, Chan CY, Chan WC, 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;44:823-9.
7. Lee SW, Lee KJ, Park CH, Kwon HJ, Kim BS. The valid diagnostic parameters in bilateral CT scan to predict unstable syndesmotic injury with ankle fracture. Diagnostics (Basel) 2020;10:812.
8. Chun DI, Cho JH, Min TH, Park SY, Kim KH, Kim JH, *et al.* Diagnostic accuracy of radiologic methods for ankle syndesmosis injury: A systematic review and meta-analysis. J Clin Med 2019;8:968.
9. Donohoe S, Alluri RK, Hill JR, Fleming M, Tan E, Marecek G. Impact of computed tomography on operative planning for ankle fractures involving the posterior malleolus. foot Ankle Int 2017;38:1337-42.
10. Black EM, Antoci V, Lee JT, Weaver MJ, Johnson AH, Susarla SM, *et al.* Role of preoperative computed tomography scans in operative planning for malleolar ankle fractures. Foot Ankle Int 2013;34:697-704.
11. Mak MF, Stern R, Assal M. Repair of syndesmosis injury in ankle fractures: Current state of the art. EFORT Open Rev 2018;3:24-9.
12. Porter DA, Jaggers RR, Barnes AF, Rund AM. Optimal management of ankle syndesmosis injuries. Open Access J Sports Med 2014;5:173-82.
13. Boyd RP, Nawaz SZ, Khaleel A. A new assessment for syndesmosis injury – The 'Chertsey test'. Injury 2016;47:1293-6.
14. Clanton TO, Williams BT, Backus JD, Dornan GJ, Liechti DJ, Whitlow SR, *et al.* Biomechanical analysis of the individual ligament contributions to syndesmotic stability. Foot Ankle Int 2017;38:66-75.
15. Vopat ML, Vopat BG, Lubberts B, DiGiovanni CW. Current trends in the diagnosis and management of syndesmotic injury. Curr Rev Musculoskelet Med 2017;10:94-103.
16. 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;35:935-41.
17. Summers HD, Sinclair MK, Stover MD. A reliable method for intraoperative evaluation of syndesmotic reduction. J Orthop Trauma 2013;27:196-200.
18. Abbasian M, Biglari F, Sadighi M, Ebrahimpour A. Reliability of postoperative radiographies in ankle fractures. Arch Bone Jt Surg 2020;8:598-604.
19. Maradit Kremers H, Larson DR, Crowson CS, Kremers WK, Washington RE, Steiner CA, *et al.* Prevalence of total hip and knee replacement in the United States. J Bone Joint Surg Am 2015;97:1386-97.
20. Dikos GD, Heisler J, Choplin RH, Weber TG. Normal tibiofibular relationships at the syndesmosis on axial CT imaging. J Orthop Trauma 2012;26:433-8.
21. 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;37:1317-25.
22. 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;18:693-8.
23. Amouzadeh Omrani F, Kazemian G, Salimi S. Evaluation of syndesmosis reduction after removal syndesmosis screw in ankle fracture with syndesmosis injury. Adv Biomed Res 2019;8:50.
24. Prior CP, Widnall JC, Rehman AK, Weller DM, Wood EV. A simplified, validated protocol for measuring fibular reduction on ankle CT. Foot Ankle Surg 2017;23:53-6.
25. Davidovitch RI, Weil Y, Karia R, Forman J, Looze C, Liebergall M, *et al.* Intraoperative syndesmotic reduction: three-dimensional versus standard fluoroscopic imaging. J Bone Joint Surg Am 2013;95:1838-43.
26. Nielson JH, Gardner MJ, Peterson MG, Sallis JG, Potter HG, Helfet DL, *et al.* Radiographic measurements do not predict syndesmotic injury in ankle fractures: An MRI study. Clin Orthop Relat Res 2005;436:216-21.
27. Pepe M, Kocadal O, Gunes Z, Calisal E, Ceritoglu K, Aktekin CN. A radiographic dye method for intraoperative evaluation of syndesmotic injuries. Foot Ankle Int 2017;38:1380-6.