Injury, Int. J. Care Injured 50 (2019) 1382–1387

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Relationship between fracture morphology of lateral malleolus and syndesmotic stability after supination-external rotation type ankle fractures

Dong-Il Chun[a], Jahyung Kim[a], Yoon Seok Kim[b], Jae-Ho Cho[c], Sung-Hun Won[a], Su-Yeon Park[d], Young Yi[b,*]

[a] Department of Orthopedic Surgery, Soonchunhyang University Seoul Hospital, 657-52 Hannam-dong Yong-San Gu, Seoul, Republic of Korea
[b] Department of Orthopedic Surgery, Seoul Paik Hospital, Inje University, 85, 2-ga, Jeo-dong, Jung-gu, Seoul, 100-032, Republic of Korea
[c] Department of Orthopedic Surgery, Chuncheon Sacred Heart Hospital, Hallym University, College of Medicine, 77, SakJu-Ro, Gyo-dong, Chun-Cheon, 24262, Republic of Korea
[d] Department of biostatistics, Soonchunhyang University Hospital, College of medicine, 657-52 Hannam-dong Yong-San Gu, Seoul, Republic of Korea

ARTICLE INFO

Keywords:
Ankle fracture
Malleolar fracture
Syndesmosis injury
SER type

ABSTRACT

Background: Syndesmotic injury with supination-external rotation (SER)-type ankle fractures are well known for the serious damages to the osseous and soft tissue envelope. However, the Lauge-Hansen classification system does not provide sufficient information related to syndesmotic injury. In this study, we aimed to investigate factors for preoperative detection of syndesmotic injury according to fracture patterns in SER III and IV ankle fractures by using radiography and computed tomography (CT).
Methods: All operative SER III and IV ankle fractures treated by a single surgeon from 2009 to 2015 were enrolled in a retrospective database. Based on computed tomographic evidence and intra-operative Cotton test, stable and unstable groups of the ankle factures were divided.
Results: A total of 52 patients with SER III, 75 patients with SER IV, and 27 patients with SER IV equivalent ankle fractures were identified, with 106 in the unstable syndesmosis group (68.8%) and 48 patients in the stable syndesmosis group (31.2%). Medial space widening and fragment angle of the fibular posterior cortex were significant predictors. The cutoff values of these factors were 4.4 mm and 32.8 degrees, respectively.
Conclusions: CT was superior to simple radiography in predicting syndesmotic injury at the preoperative period in SER-type III and IV. Medial space widening and fragment angle of the fibular posterior cortex, as predictive factors, showed significant correlations. In particular, sharper fragment angle of the posterior cortex indicated higher probability of instability that remained after fracture fixation.

Introduction

Syndesmotic injuries are often concurrent with ankle fractures, increasing the instability of the fractures and making fracture reduction and stabilization more difficult. Chronic untreated syndesmotic instability could result in pain when walking and early degenerative arthritis [1–5].

Supination-external rotation (SER)-type ankle fracture is the most frequent pattern of the operative fracture in the Lauge-Hansen classification. The SER-type III fracture is an injury involving both the lateral and posterior malleoli without damage of the medial component. The SER-type IV fracture is an injury that involves both the lateral and medial malleoli making the ankle unstable. The SER IV equivalent is a second type of unstable SER injury. It affects analogous rotational mechanism and lateral malleolar fractures although it includes a medial soft-tissue ligamentous injury with an intact medial malleolus.

These types of SER fractures require operative management due to unstable ankle [6,7]. SER injuries in the Lauge-Hansen classification system require further clarification related to concurrent syndesmotic injuries. However, these injuries cannot clarify concurrent syndesmotic injuries.

* Corresponding author at: Department of Orthopedic Surgery, Seoul Paik Hospital, Inje University, 85, 2-ga, Jeo-dong, Jung-gu, Seoul, 100-032, Republic of Korea.
E-mail addresses: orthochun@schmc.ac.kr (D.-I. Chun), hpsyndrome@naver.com (J. Kim), kimys0427@gmail.com (Y.S. Kim), hohotoy@nate.com (J.-H. Cho), orthowon@gmail.com (S.-H. Won), Suyeonpark@schmc.ac.kr (S.-Y. Park), 20vvin@naver.com (Y. Yi).

https://doi.org/10.1016/j.injury.2019.05.020
0020-1383/

Preoperative recognition on imaging studies is important for orthopedic surgeons performing surgical procedures for ankle fractures. In this study, we aimed to investigate factors for preoperative detection of syndesmotic injury according to fracture patterns in SER III and IV ankle fractures by using radiography and computed tomography (CT).

Materials and methods

Study group selection

We used an institutional review board-approved trauma registry with retrospectively collected clinical and radiological data containing all ankle fractures. All operative SER III and IV ankle fractures treated by a single surgeon from 2009 to 2015 were enrolled.

Preoperative ankle three-dimensional CT reconstruction were performed for all patients in both ankles, using 64-slice multidetector CT (MDCT) canner (Aquilion Model TSX-101A, TOSHIBA medical systems corporation, Shimoishigami, Japan). Demographic data, including age and sex as well as injury mechanism, were recorded. The inclusion and exclusion criteria of this study are summarized in Table 1.

Operative technique and group dividing

SER-type ankle fractures were divided into two groups based on computed tomographic evidence of tibio-fibular displacement at the syndesmotic lesion before surgery. Open reduction and internal fixation of the fibular fracture was done using standard AO technique. Then, the distal tibiofibular articulation was directly exposed anteriorly, utilizing the same posterolateral approach that was used for open reduction and internal fixation of the fibula. Dissection is performed until the disrupted anterior inferior tibiofibular ligament is visualized. The distal fragment of the fibular was pulled distally and rotated internally via a small clamp to reduce the distal tibiofibular articulation by attempting to center the fibula within the tibial incisura, and confirming fluoroscopic reduction of the syndesmosis using standard radiographic parameters and direct visualization.

An unstable syndesmotic injury was confirmed on the Cotton test, intraoperatively after all fractures were internally fixed and was defined as a tibio-fibular clear space of >5 mm. Syndesmotic screw fixation was performed using a 4.0-mm cortical screw when unstable syndesmotic injuries were diagnosed [4,8–11].

Majority of SER-type ankle fractures with tibio-fibular displacement preoperatively in the CT scan showed positive cotton test intraoperatively. However, nine patients had syndesmotic injury with tibio-fibular instability intraoperatively during the cotton test. According to preoperative and intraoperative syndesmotic evaluation, the patients were assigned into two groups: the unstable syndesmotic group and the stable syndesmotic group.

CT scan evaluation

Bilateral ankle CT scans were obtained preoperatively to assess for gross articular and syndesmotic tibio-fibular displacement to determine whether syndesmotic operation was necessary. CT of the ankle was performed using a CT scanner (SOMATOM Definition Edge, SIEMENS, Germany), with 120 kVp, 150-mm field of view, on 0.5-mm interval. CT scans were conducted with the patient in the supine position. Multi-detector CT and three-dimensional reconstructions were performed.

A syndesmotic tibio-fibular displacement was determined by calculating the difference in distance from the anterior and posterior aspects of the tibial incisura to the fibula for both the injured and uninjured ankles. All measurements were made 1 cm superior to tibial plafond for each ankle.

On preoperative ankle radiographs, four parameters that describe lateral malleolar fracture patterns were measured: fracture height of the anterior cortex defined as the vertical height between the distal tibial articular surface and most obvious fracture line of anterior cortex of lateral malleolus (Fig. 1A), fracture height of the posterior cortex defined as the vertical height between the distal tibial articular surface and most obvious fracture line of posterior cortex of lateral malleolus (Fig. 1B), fragment angle between the fracture line and posterior cortex of the lateral malleolus (Fig. 1C, *below*: fragment angle), and medial joint space defined as perpendicular length between the medial malleolus articular surface and medial talar articular surface on the plane of intercollicular groove on coronal view(Fig. 1D). Fragment angle was measured because it showed association according to fracture height difference between the anterior and posterior cortex.

Reliability test

Radiographic measurements were performed on 2 separate occasions by 2 independent investigators in a blinded manner. The investigators were simultaneously instructed by a surgeon who was trained in foot and ankle surgery. Each investigator then practiced taking measurements on sample radiographs while being observed. The investigators were blinded to one another's measurements and to their own previous measurements. Each set of measurements was obtained with a minimum interval of 3 months to ensure that the previous alignment angle measurements would not be remembered. Interobserver and intraobserver reliability was determined by calculating the intraclass correlation coefficients for continuous data; the interobserver and intraobserver class measurements of all of the radiographic parameters were satisfactorily correlated (Table 2).

Statistical analysis

A priori power analysis was performed to determine appropriate sample size. Both study groups showed a power of 0.9 for detecting a Δintercept of 2 at an alpha level of 0.05. The minimum number of subjects required to satisfy this condition for the smaller group was 78.

All of the groups had not a normal distribution according to the Shapiro-Wilk normality test. Comparison between the unstable and stable syndesmotic groups was conducted using a *t*-test or Mann-Whitney U test and a chi-square test according to the data characteristics. Receiver operating characteristic (ROC) curves were used to evaluate classification and optimal cutoff values were estimated for every effective radiologic value following youden index method. To combine the factors that significantly contributed to unstable syndesmotic injuries, binary logistic regression with the stepwise selection method using CT measurements was used. A p-value <0.05 was considered statistically significant in the logistic regression analysis. All statistical analyses were performed with SPSS version 25.0 and R version 3.3.1('OptimalCutpoints' packages).

Table 1
Inclusion and exclusion criteria for patients in this study.

Inclusion criteria
An ankle fracture classified as SER-type III, IV, or SER IV equivalent injury.
Exclusion criteria
(1) Patients with a CT scan performed at an outside hospital
(2) Patients who do not agree with both ankle CT scans
(3) An ankle fracture resulting from a direct blow
(4) Abnormal ankle anatomy of the ipsilateral and contralateral lowerlimb

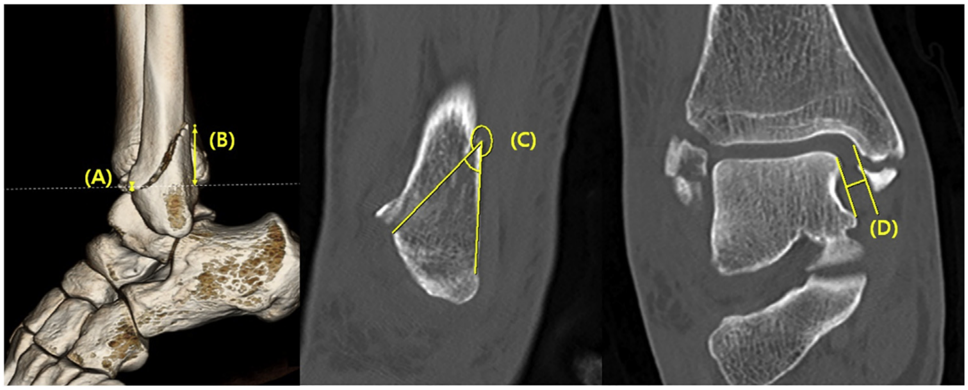

Fig. 1. Three dimensional reconstructed image(A,B), sagittal image and coronal image on CT scan showing four parameters which describes lateral malleolar fracture patterns. **(A)** Fracture height of the anterior cortex. **(B)** Fracture height of the posterior cortex. **(C)** Fragment angle. **(D)** Medial joint space (perpendicular distance between the articular surface of the medial malleolus and the medial talar articular surface on the coronal view of computed tomography).

Table 2
Intraobserver and interobserver reliabilities of measurements.

	Intraobserver reliability		Interobserver reliability	
Measurement CT scan	ICC	95% CI	ICC	95% CI
Fracture height - anterior cortex	0.90	0.79–0.97	0.92	0.87–0.99
Fracture height - posterior cortex	0.91	0.79–0.97	0.90	0.79–0.96
Fragment angle*	0.88	0.78–0.97	0.89	0.78–0.98
Medial joint space	0.92	0.87–0.97	0.93	0.86–0.99

* Fragment angle means the angle between the fracture line and posterior cortex of the lateral malleolus.

Results

A total of 590 patients with an ankle fracture underwent operative treatment from May 2009 to December 2015. Among these patients, 154 with SER III, IV, and IV equivalent type ankle fractures were included. A total of 52 patients with SER III, 75 patients with SER IV, and 27 patients with SER IV equivalent ankle fractures were identified, with 106 in the unstable syndesmosis group (68.8%) and 48 patients in the stable syndesmosis group (31.2%) (Fig. 2). Patient demographics and co-morbidities were similar between the two groups. The mean age (and standard deviation) of the patients at the time of surgery was 47.7 ± 17.7 years.

The comparison between the unstable and stable syndesmotic groups showed that age, Fracture height of the posterior cortex, fragment angle, and medial joint space on CT scans were significantly different between the two groups ($p < 0.05$ for all) (Table 3).

Multiple logistic regression model using stepwise selection method, age, fracture height of the posterior cortex, fragment angle, and medial joint space on CT scans, showed that fragment angle and medial joint space on CT were significant contributing factors to unstable syndesmotic injury (Table 4).

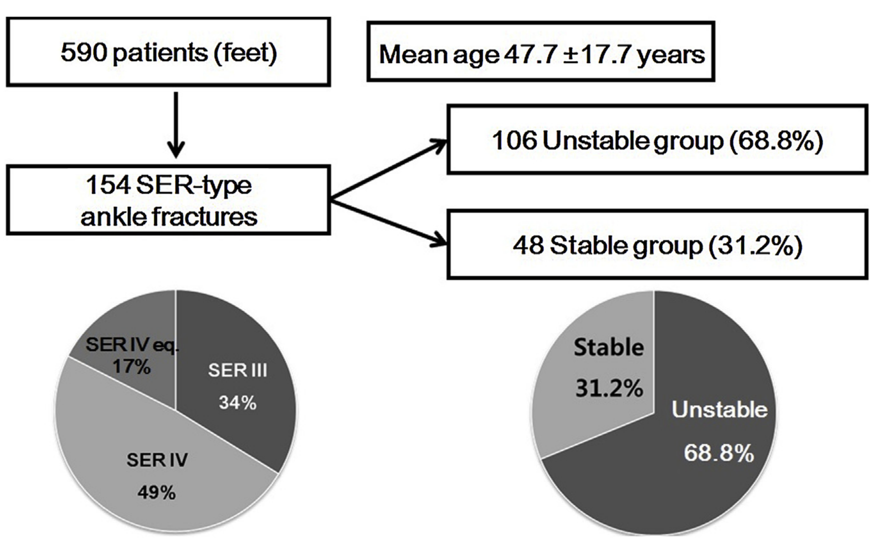

Fig. 2. Flow diagram of the involved patients. Total of 590 patients with an ankle fracture who underwent operative treatment were included in the study. 154 SER-type ankle fractures were included. Of these patients, 106 were classified as unstable syndesmotic group and 48 were as stable syndesmotic group. The mean age was 47.7 ± 17.7 years.

Table 3
Comparison between the unstable and stable syndesmotic injury groups.

	Unstable syndesmosis group (N = 80)	Stable syndesmosis group (N = 78)	p value
Age	38.4 ± 16.8	51.1 ± 17.9	<**0.05**
CT scan			
Fracture height - anterior cortex (mm)	1.6 ± 2.2	0.2 ± 0.9	>0.05
Fracture height - posterior cortex (mm)	3.2 ± 1.7	1.6 ± 1.1	<**0.001**
Fragment angle* (degree)	22 degrees	37 degrees	<**0.001**
Medial joint space	5.80 ± 1.7	3.82 ± 2.6	<**0.001**

Table 4
Logistic regression analysis of the unstable and stable syndesmotic groups (Performed upon categorical variables).

	p value	Odd ratio(95% CI)
Age	0.797	0.955-1.036
CT		
Fracture height -posterior cortex (mm)*	**Not applicable**	
Fragment angle (degree)	**0.008**	2.461–449.185
Medial joint space	**0.000**	6.010–288.958

* Multicolinearity was detected between fracture height of posterior cortex and Fragment angle. Therefore fracture height – posterior cortex was not accessed losgistic regression analysis.

The ROC curve showed that fragment angle was useful to determine cutoff values for unstable syndesmotic injuries (Fig. 3A). The area under the curve (AUC) for fragment angle on CT was 0.86 (0.796-0.923), and the appropriate cutoff value was 32.9 degrees. When a fragment angle of <32.9 degrees on a CT scan was used as a threshold, a sensitivity of 89.4% and a specificity of 72.6% were achieved to determine unstable syndesmotic injuries in SER-type ankle fractures.

The ROC curve showed that medial joint space was useful to determine cutoff values for unstable syndesmotic injuries (Fig. 3B). The AUC for medial joint space widening on CT was 0.826 (0.740-0.892), and the appropriate cutoff value was >4.4 mm. When a medial joint space widening of >4.4 mm on a CT scan was used as a threshold, a sensitivity of 85.4% and a specificity of 80.2% were achieved to determine unstable syndesmotic injuries in SER-type ankle fractures.

On the other hand, the ROC curve showed that fracture height of the posterior cortex was useful to determine cutoff values for unstable syndesmotic injuries (Fig. 3C). The AUC for medial joint space widening on CT was 0.540 (0.469-0.610), and the appropriate cutoff value was >8.27 mm. When a fracture height of the posterior cortex of 8.27 mm on a CT scan was used as a threshold, a sensitivity of 12.8% and a specificity of 99.1% were achieved to determine unstable syndesmotic injuries in SER-type ankle fractures. Fracture height of the posterior cortex showed significant contributing factors ($p < 0.05$), but there is no correlation in logistic regression analysis performed upon categorical variables. ($p > 0.01$)

Discussion

SER injuries are the most common type of ankle fracture [12–17]. Unstable SER fractures that are left untreated are known to develop degenerative changes within the ankle joint [18]. Syndesmotic injuries are often concurrent with ankle fractures, increasing the instability of the fractures and making fracture reduction and stabilization more difficult. Therefore, in the case of syndesmotic injuries, predicting whether the internal fixation of the fracture in the surgical treatment is sufficient or whether the syndesmotic fixation with internal fixation is necessary is important.

Stage 3 and 4 pronation-external rotation injuries and stage 3 pronation-abduction injuries in the Lauge-Hansen classification system frequently coincide with syndesmotic injuries, which correspond to Danis-Weber type-C fractures [19]. Supination-adduction injuries in the Lauge-Hansen classification system rarely occur concurrently with syndesmotic injuries, which correspond to Danis-Weber type-A fractures [19]. However, SER injuries in the Lauge-Hansen classification system, corresponding to Danis-Weber type-B fractures, require further clarification related to concurrent syndesmotic injuries [20].

The ankle fractures of the SER type were interpreted as Danis Weber type B because they are based on the fracture level of the anterior cortex, which is the lower height of the fracture. In particular, SER III, IV, and IV equivalent ankle fractures did not show a significant difference in the degree of damage to the anterior fibula. However, the fracture pattern of the posterior cortex at the SER type showed varying degrees of damage, and the stability of the ankle joint was also influenced by the fracture pattern.

In this study, the anterior and posterior heights were measured separately. To intuitively understand these heights, fragment angle, which is the angle formed by these indicators, was measured from the lateral side.

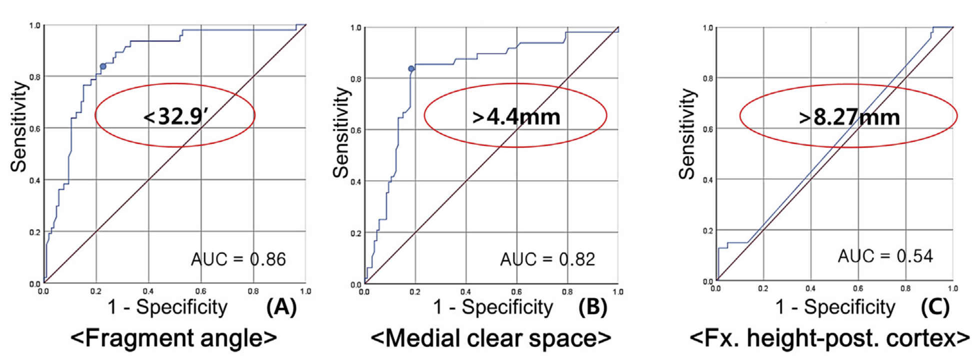

Fig. 3. Receiver operating characteristic curve of the preoperative fragment angle, medial clear space and fracture height (anterior and posterior cortex) measurements between the unstable and stable syndesmotic groups. The (A) curve defines the cutoff value of the preoperative fragment angle as 29.1 degrees. The (B) curve defines the cutoff value of the preoperative medial clear space as 5.7 mm. The (C) curve defines the cutoff value of the preoperative fracture height of the posterior cortex as 8.27 mm.

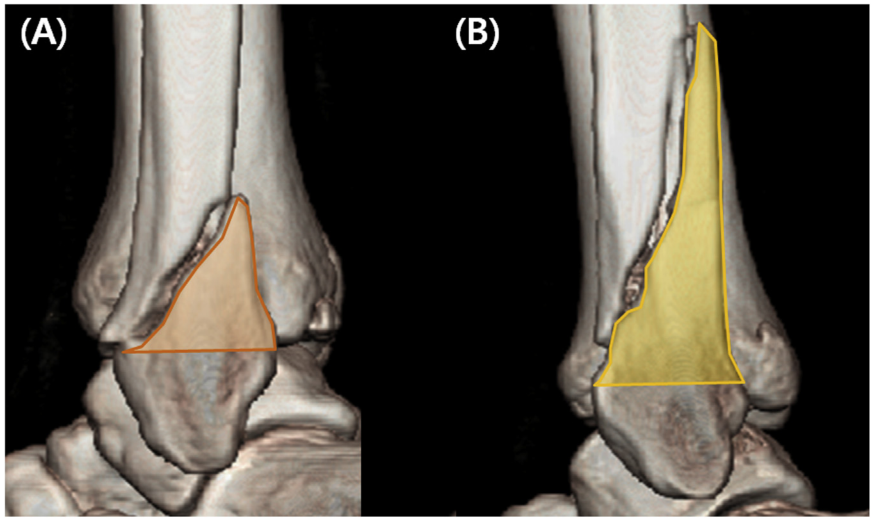

Fig. 4. Comparison of the area between fracture fragments forming acute (B) and obtuse (A) angle of the fibular posterior cortex. If the angle were acute (B), the amount of transmitted force becomes larger, resulting wider area of syndesmotic ligament complex damage.

The ankle syndesmosis consists of antero-inferior tibiofibial ligament (AITFL), interosseous membrane (IOM), and posterior-inferior tibiofibial ligament (PITFL). In the SER type, the fracture is present around the AITFL [21–24]. However, IOM or PITFL damage may accompany depending on the type of fracture, which makes it easy to cause unstable syndesmotic injury. Posterior malleolar fracture is attached to PITFL, and unstable posterior malleolar fracture fragments have been reported to affect syndesmotic stability [21,24,25]. Therefore, not only the fracture pattern of the anterior cortex on the fibula, but also that of the posterior cortex also contributes to syndesmotic stability.

The present study investigated factors that could be used to detect unstable syndesmosis after open reduction internal fixation (ORIF) concurrent with SER-type ankle fractures preoperatively and to provide cutoff values based on preoperative CT and radiographic measurements. Fracture height of the posterior malleolus, medial joint space, and fragment angle were significant preoperative factors that were associated with unstable syndesmotic injuries. Based on the results, no parameter could validate syndesmotic stability in radiographs. However, in CT scan, widening of medial joint space and acute fragment angle were significantly associated with unstable syndesmotic injury.

Medial joint space widening is known to significantly correlate with syndesmotic injury [26]. Significance was also confirmed in the present results on the values measured on CT scans,

Our results showed that medial joint space widening was a significant preoperative parameter to predict syndesmotic stability in the coronal plane of the CT scan. We hypothesized that the height of the posterior malleolus would be significantly related to syndesmotic instability after internal fixation and the correlation was proven.

On the other hand, fragment angle was found to be more significantly correlated. It can be easily decided by the posterior height because most of the fracture line of the fibular anterior cortex is located around the AITFL. Fragment angle can show more significant result because posterior height can be influenced by bone size.

If the fracture forms an acute angle, IOM damage may occur in a wider area and fracture size beneath the posterior fracture may be larger, which can all cause unstable syndesmotic injury. In the present results, medial joint space widening was a powerful preoperative parameter to predict syndesmotic stability in the sagittal plane of the CT scan. We think fragment angle also can be one of preoperative parameter to predict syndesmotic stability (Fig. 4).

This study has the following drawbacks. First, data collection was retrospectively performed. In addition, study period was calculated to investigate the significant level of the experimental group. Second, the strength of the external force that caused the fracture could not be measured quantitatively. In previous studies, injury energy was divided to high and low depending on the injury mode. Since the external force that caused the actual fracture was impossible to measure quantitatively, no analysis based on the injury mode was performed. Third, the measured parameters (units expressed in millimeter) were not analyzed according to height and weight. Several patients showed a 1.5-fold difference in skeletal structure between male and female. Dividing male and female is better in obtaining the meaningful optimal cutoff value of posterior height at least.

However, this study analyzed the significance of various factors that predicted syndesmotic stability at the preoperative period. This will help predict and treat syndesmotic instability that remains after fixation of the fracture site.

Conclusion

CT was superior to simple radiography in predicting syndesmotic injury at the preoperative period in SER-type III and IV. Medial space widening and fragment angle of the fibular posterior cortex, as predictive factors, showed significant correlations. In particular, the more acute the fragment angle of the posterior cortex, the higher the probability of instability remains after fracture fixation.

A source of funding

There was no involvement of any funding source in the study.

Transparency document

The Transparency document associated with this article can be found in the online version.

Acknowledgement

This work was supported by the 2018 Inje University(South Korea) research grant.

References

[1] Grass R, Rammelt S, Biewener A, Zwipp H. Peroneus longus ligamentoplasty for chronic instability of the distal tibiofibular syndesmosis. Foot Ankle Int 2003;24(May (5)):392–7.

[2] Porter David A, Jaggers Ryan R, Barnes Adam Fitzgerald, Rund Angela M. Optimal management of ankle syndesmosis injuries. Open Access J Sports Med 2014;5:173–82.

[3] Morris MW, Rice P, Schneider TE. Distal tibiofibular syndesmosis reconstruction using a free hamstring autograft. Foot Ankle Int 2009;30(June (6)):506–11.

[4] van den Bekerom MP. Diagnosing syndesmotic instability in ankle fractures. World J Orthop 2011;2(July (7)):51–6.

[5] van den Bekerom MP, de Leeuw PA, van Dijk CN. Delayed operative treatment of syndesmotic instability. Current concepts review. Injury 2009;40 (November (11))1137–42 Epub 2009 Jun 12.

[6] Gill JB, Risko T, Raducan V, Grimes JS, Schutt Jr. RC. Comparison of manual and gravity stress radiographs for the evaluation of supination-external rotation fibular fractures. J Bone Jt Surg Am 2007;89(5):994–9.

[7] Pakarinen H. Stability-based classification for ankle fracture management and the syndesmosis injury in ankle fractures due to a supination external rotation mechanism of injury. Acta Orthop Suppl 2012;83:1–26.

[8] Franke J, von Recum J, Suda AJ, Grützner PA, Wendl K. Intraoperative three dimensional imaging in the treatment of acute unstable syndesmotic injuries. J Bone Joint Surg Am 2012;94(August (15)):1386–90.

[9] 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(October (9)):604–9.

[10] Pakarinen H, Flinkkilä T, Ohtonen P, Hyvönen P, Lakovaara M, Leppilahti J, et al. Intraoperative assessment of the stability of the distal tibiofibular joint in supination-external rotation injuries of the ankle: sensitivity, specificity, and reliability of two clinical tests. J Bone Joint Surg Am 2011;93(November (22)):2057–61.

[11] Stoffel K, Wysocki D, Baddour E, Nicholls R, Yates P. Comparison of two intraoperative assessment methods for injuries to the ankle syndesmosis. A cadaveric study. J Bone Joint Surg Am 2009;91(November (11)):2646–52.

[12] Court-Brown CM, McBirnie J, Wilson G. Adult ankle fractures–an increasing problem? Acta Orthop Scand 1998;69:43–7.

[13] Juto Hans, Nilsson Helena, Morberg Per. Epidemiology of Adult Ankle Fractures: 1756 cases identified in Norrbotten County during 2009–2013 and classified according to AO/OTA. BMC Musculoskelet Disord 2018;19(441).

[14] Russo A, Reginelli A, Zappia M, Rossi C, Fabozzi O, Cerrato M, et al. Ankle fracture: radiographic approach according to the Lauge-Hansen classification. Musculoskelet Surg 2013;97(Suppl 2):S155–60.

[15] Hintermann B, Regazzoni P, Lampert C, Stutz G, Gächter A. Arthroscopic findings in acute fractures of the ankle. J Bone Joint Surg Br 2000;82:345–51.

[16] Jensen SL, Andresen BK, Mencke S, Nielsen PT. Epidemiology of ankle fractures. A prospective population-based study of 212 cases in Aalborg, Denmark. Acta Orthop Scand 1998;69:48–50.

[17] Kristensen KD, Hansen T. Closed treatment of ankle fractures. Stage II supination-eversion fractures followed for 20 years. Acta Orthop Scand 1985;56:107–9.

[18] Gougoulias N, Khanna A, Sakellariou A, Maffulli N. Supination-external rotation ankle fractures: stability a key issue. Clin Orthop Relat Res 2010;468:243–51.

[19] Harper MC. Ankle fracture classification systems: a case for integration of the Lauge-Hansen and AO-Danis-Weber schemes. Foot Ankle 1992;13(September (7)):404–7.

[20] Choi Y, Kwon SS, Chung CY, Park MS, Lee SY, Lee KM. Preoperative radiographic and CT findings predicting syndesmotic injuries in supination-external rotation-type ankle fractures. J Bone Joint Surg Am 2014;96(14):1161–7.

[21] Yuen Chi Pan, Lui Tun Hing. Distal tibiofibular syndesmosis: anatomy, biomechanics, injury and management. Open Orthop J 2017;11(Suppl-4, M7):670–7.

[22] Candal-Couto JJ, Burrow D, Bromage S, Briggs PJ. Instability of the tibio-fibular syndesmosis: have we been pulling in the wrong direction? Injury 2004;35 (8):814–8.

[23] Nielson JH, Sallis JG, Potter HG, Helfet DL, Lorich DG. Correlation of interosseous membrane tears to the level of the fibular fracture. J Orthop Trauma 2004;18(2):68–74.

[24] Oae K, Takao M, Naito K, Uchio Y, Kono T, Ishida J, et al. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis. Radiology 2003;227(1):155–61.

[25] Yi Young, Chun Dong-Il, Won Sung Hun, Park Suyeon, Lee Sanghyeon, Cho Jaeho. Morphological characteristics of the posterior malleolar fragment according to ankle fracture patterns: a computed tomography-based study. BMC Musculoskelet Disord 2018;19(51).

[26] Choi Young, Kwon Soon-Sun, Chung Chin Youb, Park Moon Seok, Lee Seung Yeol, Lee Kyoung Min. Preoperative Radiographic and CT Findings Predicting Syndesmotic Injuries in Supination-External Rotation-Type Ankle Fractures. J Bone Joint Surg Am 2014;96:1161–7.