A preliminary study of an ultrasound-based method for measuring talar displacement during the anterior drawer stress test using a Telos device

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Research

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Abstract

Background

Conventionally, X-ray examination has been performed to quantify the instability of the ankle joint. The aim of this study was to evaluate the reliability and validity of a new ultrasound-based examination for the quantitative detection of ankle instability, and whether the present examination could replace the conventional X-ray test.

Methods

Thirteen adults were recruited for this validation study and were divided into two groups: a control group (eight adults, 16 feet) and an ankle instability (AI) group (five adults, eight feet). The control group had Cumberland Ankle Instability Tool (CAIT) scores ≥ 25 points, and the AI group had CAIT scores < 25 points. Anterior drawer stress tests were performed using a Telos device with ultrasound (0–150 N) and X-ray (0, 120, and 150 N). The stress ultrasound was performed by two examiners, and changes in the anterior talar displacement were measured by two measurers. The inter-examiner and inter-measurer reliabilities were calculated in the control group, and correlations between stress ultrasound and conventional stress X-ray imaging results were examined at 120 and 150 N in both the control and AI groups.

Results

Ultrasound imaging detected changes in the anterior talar displacement under loads greater than 70 N. The inter-examiner and inter-measurer reliability of the ultrasound-based method were moderate and excellent, respectively, at 150 N. The tibiotalar distances observed with X-ray and ultrasound imaging at 120 N were highly correlated in the AI group.

Conclusion

The ultrasound-based method was comparable to the conventional X-ray method and represents a novel radiation-free method for the detection of ankle instability. This method has the potential for clinical application to quantitatively evaluate mechanical instability.

Background

Ankle sprains, especially lateral ligament strains caused by inversion and internal rotation stresses to the ankle [1, 2] are the most common sports injuries, and the anterior talofibular ligament (ATFL) is the most commonly injured ligament [3]. In addition, up to 70% of patients with a history of lateral ankle sprains,
including rupture of the lateral ankle ligaments and repeated injuries within a short time period, will eventually develop chronic ankle instability (CAI) [4, 5].

CAI is mainly characterized by recurrent sprains, episodes of giving way, and feelings of instability [4]. CAI is thought to result from both mechanical factors, including the effects of injuries on the joint capsule and the laxity of the ATFL and calcaneofibular ligaments; and functional factors, including central and peripheral nervous system disorders and muscle dysfunction; for example centrally mediated changes to motor control strategies of both the injured and non-injured limbs and delayed muscular activation reaction time in the peroneus longus and brevis muscle activation [6–8]. CAI has deleterious effects not only on sports-related activities, such as declining performance and halting activity, but also on the activities associated with daily living [9]. Ligament reconstructive surgery and long-term rehabilitation are often necessary to restore normal function. Traditional surgical reconstruction procedures for CAI to stabilize the ankle using tendon grafts placed non-anatomically can result in a stable ankle [10]. However, there is a high possibility that these procedures, such as the Chrisman–Snook reconstruction, may over-constrain both the ankle and subtalar joints, resulting in limitation of joint motion and long-term development of degenerative arthritis [11]. Contemporary surgical techniques emphasize anatomic repair of the torn ligaments to restore stability of the ankle while attempting to minimize these complications. It is also the consensus of orthopedic specialists that the primary or secondary suturing of the torn lateral ligaments with augmentation by transfer of the extensor retinaculum (Broström–Gould procedure) is the appropriate first-line consideration for patients with chronic ankle lateral ligament laxity requiring surgical treatment [12]. However, a Cochrane systematic review reported that there is insufficient evidence to support any surgical intervention over another, and indicated the propensity for surgical intervention for CAI to have a higher risk of complications compared with conservative intervention [13]. Therefore, to detect and determine the optimal treatment earlier after the injury is necessary to avoid the result of CAI and to avoid ligament reconstruction surgery in the future.

The current diagnostic measures for ankle instability mainly include manual anterior drawer tests and stress X-ray tests using a stress device [14, 15]. Among these tests, the stress X-ray test is the only method that provides an objective and quantitative diagnosis. Manual anterior drawer stress tests are difficult to assess quantitatively because they depend on the experience and subjective feeling of the examiner [16, 17]. The assessment of ankle instability using the stress X-ray test can be applied to determine the severity of an injury and to predict the required period of rest before returning to athletic activities [18]. However, the X-ray stress test is not without disadvantages, including the inconvenience of moving to a separate examination room and exposure to X-ray radiation. Because of the recent increase in medical radiation exposure, we need a quantitative examination for the diagnosis of ankle instability without requiring X-ray exposure. Although some examinations to diagnose CAI using ultrasound imaging were developed without X-ray exposure, these have not yet reached clinometric and quantitative abilities [19–21]. Ultrasound examination has several advantages over other modalities because it can allow ligaments and cartilage to be observed dynamically, quickly, and without [22, 23] clinicians to gain a better view of soft tissues and cartilage, many reports have described its use for the diagnosis of rheumatic diseases and for orthopedic surgery, in which ultrasound assists in the triage of foot disorders and during follow-up
and postoperative evaluations of muscle-tendon injuries [24–26] sound has been used to assess the severity of ankle or ligament damage and avulsion fractures [27–29] have classified the severity of ligament injury using ultrasound imaging and reported its sensitivity and specificity in the diagnosis of chronic lateral ankle ligament injury [28]. Furthermore, compared with X-ray or magnetic resonance imaging (MRI), ultrasound examinations can be quickly conducted over a wide range of locations because of the mobility of its small-sized apparatuses. These apparatuses are frequently used for the examination of the ankle joint area to visualize fine bone fragments that result from fractures or damage and tearing of ligaments. In recent years, diagnostic ultrasound devices have attracted much attention owing to these advantages.

A number of studies have reported on ultrasound examinations while applying an anterior drawer force to evaluate ankle instability following an injury to the ATFL [14, 19, 20]ison between ultrasound stress imaging and a stress X-ray test for the assessment of ankle ligament damage [14]; however, in their study, the stress force was loaded by hand, making it difficult to quantify the diagnostic evaluation. Croy et al. compared the differences in lateral ankle laxity with CAI, ankle sprain copers, and healthy groups using stress ultrasound with a Telos device [19]. Although it was difficult to detect the differences by the average length of ATFL, they showed group differences between the CAI and coper groups and the healthy group. However, the change in ATFL length according to the loads of the anterior drawer test, and the comparison with the conventional X-ray stress imaging must be verified. Oae et al. evaluated the ATFL using three devices: stress X-ray, normal ultrasound, and MR imaging [20]. They compared only the sensitivity of the diagnosis between them; however, they did not utilize the stress ultrasound test. Moreover, Cho et al. evaluated MRI examinations, stress X-ray tests, and ultrasound stress imaging to assess participants with ankle instability, and the loosening of the ATFL was confirmed by ultrasound imaging in all cases [15]. Because they loaded the stress manually without any devices, it was difficult to quantify the stress values and to estimate the ankle instability quantitatively. Each study is very meaningful and important; however, to replace stress X-ray with stress ultrasound to avoid medical radiation exposure, it is necessary to evaluate the displacement of the talus in response to load forces, its reliability, and the comparison with the conventional stress X-ray.

This study is the first preliminary study to detect the anterior talar displacement at various loads during the anterior drawer test using a Telos quantitative loading device and stress ultrasound, and to compare the results with those obtained from conventional stress X-ray tests.

**Methods**

**Participants**

This research was approved by the Ethics Application Committee of Hokkaido University, Faculty of Health Sciences (approval number: 18–59). A sufficient explanation was given to the participants, and all experiments were carried out after obtaining informed consent from them. The participants were divided into two groups, that is, the control group and the ankle instability (AI) group. For the control group, we
recruited eight healthy volunteers (16 feet, mean age: 22.1 years) with the following conditions: (1) no history of fracture, (2) no history of ankle sprain within three years, and (3) no history of repeated ankle sprains. The participants had self-evaluated Cumberland Ankle Instability Tool (CAIT) scores, which is currently the internationally recommended questionnaire for self-evaluation of ankle instability [4]. The CAIT scores were ≥ 25 points for the control group. For the Al group (five volunteers, eight feet, mean age: 23.2 years), the CAIT scores were less than 25 points [4,30]. Group were recruited without a clinical diagnosis, but they were required to have a subjective feeling of pain and instability, giving way, or recurring sprains. The exclusion criteria included a history of fractures, a sprain within the previous year, and hospital visits within one year [4]. The participants were also evaluated using the Karlsson Ankle Functional Score (KAFS) to measure ankle joint function [31].

Procedures

Anterior drawer stress test

The stress was loaded using a Telos stress device (GAIIS/E; Telos Arztund Krankenhausbedarf GmbH, Hungen, Germany). The front pressure cushion of the Telos device was situated 5 cm above the medial malleolus.

Positioning

The position of the participants during both ultrasound and X-ray imaging was the standard ankle lateral radiograph, as follows: the popliteal fossa of the examinee’s side was tightly applied to the pole of the Telos, and the knee joint was bent to 60° with the patella facing anteriorly and the tibia lying parallel to the table; the medial malleolus and lateral malleolus were aligned and kept perpendicular to the examination table. The heel was pushed against the Telos, and the angle of the ankle joint was 0° (Fig. 1).

Ultrasound stress imaging tests

All ultrasound images were acquired using an Ascendus (Hitachi ALOKA Medical, Ltd. Tokyo, Japan) with EUP-L75 probe (38 mm linear, 4-18MHz) and scanning at a fixed depth of 40 mm. The probe was placed slightly inside the Achilles tendon from the rear of the ankle along the direction of the major axis. The examiner adjusted the focus at the posterior process of the talus. The tibia and the medial tubercle of the posterior process of the talus could be clearly visualized so that the posterior tibia was as long as possible (Fig. 2). The distance between the tibia and the talus was measured as the shortest distance from the tibia backward of the cortical bone border posterior extension line to the medial tubercle of the posterior process of the talus (Figs 2 and 3). In the control group, ultrasound images were obtained one image sequentially every 10 N from 0 to 150 N. In the Al group, one ultrasound image was obtained at 0, 120, and 150 N each. The anterior displacement of the talus in response to the stress exerted by the Telos device was then measured. Data were expressed as the difference in tibiotalar distance at the respective stress load. The distances between the tibia and the talus were measured using Image J ver. 1.48v (National Institutes of Health, Bethesda, MD, USA).
Stress X-ray tests

All participants underwent stress X-rays. Stress X-ray tests were conducted at 0, 120, and 150 N and images were taken sequentially. We evaluated the distance between the tibia and the talus via X-ray by measuring the shortest distance between the distal portion of the rear tibia (lip) to the talar border (Fig. 4). The amount of anterior talar displacement at 120 and 150 N was calculated with reference to the position at 0 N (Figs 3 and 4). The measurements were made using medical image viewer software, EV Insite R. ver.3.1.1.204 (PSP Co., Tokyo, Japan).

Examiners and measurers

The examiners were two radiology technologists with more than three years of clinical experience each in ultrasound imaging, and the measurers were two experts in ultrasound imaging who assessed the tibiotalar distance from the images taken by the examiners. The examiners physically applied probes to the participants’ ankle joints and then captured images of the tibial cortical bone trailing edge and the posterior talar bone inner nodule. Using these images, the measurers determined the shortest distances in millimeters between the tibial cortical bone trailing extensions and the posterior talar process inner nodules. Each examiner and measurer performed the inspection and measurement once, and the same examiners and measurers were always used. The role of the examiner and the measurer was separated, that is, the examiners only performed the ultrasound examination and the measurers only measured the distances from the resulting images. The two examiners performed the ultrasound on the same day for the same participant. The two measurers analyzed the images separately the day after the stress test without any information about the participants. The X-ray examination was performed by an experienced radiology technologist. The examiners and the measurers were not informed about the X-ray images and the self-evaluation scores.

Statistical Analyses

All statistical analyses except Bland–Altman analysis were performed using SPSS Statistics v.18 (IBM Corp., Armonk, NY, USA). Comparisons between two groups were performed using the Mann–Whitney U test. Differences in the amounts of anterior talar displacement under each load were analyzed using analysis of variance (ANOVA) with Tukey’s honestly significant difference (HSD) multiple comparisons test. Error bars represent standard deviation (SD). A p-value of less than 0.05 was considered statistically significant. Inter-examiner and inter-measurer reliability were calculated using intraclass correlation coefficients (ICCs) [i.e., ICC(2,1) and ICC(2,1), respectively]. ICCs were classified according to the evaluation criteria by Koo et al., where a value above 0.9 was classified as excellent reliability, those between 0.75 and 0.9 as good reliability, those between 0.5 and 0.75 as moderate reliability, and those less than 0.5 as poor reliability [32]. The standard error of the mean (SEM) was calculated by dividing the standard deviation by the square root of the sample size. The coefficient of variation (CV) was calculated by dividing the standard deviation by the average, and the minimum detectable change at the 95% confidence level (MDC95) was calculated using the following formula: MDC95 = SEM × 1.96 × √2 (the
value 1.96 is the z score associated with the 95% confidence level). Correlations between the measurements of the anterior talar displacement obtained from ultrasound or X-ray images were estimated using Pearson’s correlation analysis. Probability values \( p < 0.05 \) were considered statistically significant. R values were classified as follows: a value above 0.9 was very high, a value between 0.70 and 0.9 was high, a value between 0.40 and 0.70 was moderate, a value between 0.20 and 0.40 was weak, and a value below 0.20 was very weak (Rowntree, 1981; Overholser and Sowinski, 2008).

## Results

### Self-evaluation of ankle instability

First, we compared the scores for the self-assessment of ankle instability using the CAIT questionnaire. The average CAIT score of the control group (eight participants, 16 ankles) was 29.5 ± 1.21, and the average score of the AI group was 17.7 ± 6.22. The scores for the AI group were significantly lower than those of the control group by 60% \( (p < 0.01; \text{Fig. 5A}) \). The KAFS also suggested that the control group had significantly higher scores than the AI group (Fig. 5B).

### Validation of the ultrasound-based method

To validate our newly proposed ultrasound-based method to detect the anterior displacement of the talus during the anterior drawer test, we quantified the distances between the talus and the tibia under different loads using the control group. The anterior displacement of the talus increased in response to the load forces applied by the Telos (Fig. 6). ANOVA revealed a significant anterior displacement from 0 N at loads >70 N \( (p=0.012) \), as shown in Fig. 6 and Table 1.

### Table 1 Average scores of the anterior displacement for each stress load

| Stress load (N) | 10  | 20  | 30  | 40  | 50  | 60  | 70  | 80  |
|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Displacement* (mm) | 0.326 | 0.253 | 0.404 | 0.500 | 0.597 | 0.841 | 1.019 | 1.231 |
| SD †             | 0.365 | 0.500 | 0.483 | 0.715 | 0.729 | 1.012 | 1.083 | 1.048 |
| p-values‡        | 0.997 | 1.000 | 0.978 | 0.875 | 0.649 | 0.105 | 0.012 | 0.000 |

| Stress load (N) | 90  | 100 | 110 | 120 | 130 | 140 | 150 |
|-----------------|-----|-----|-----|-----|-----|-----|-----|
| Displacement* (mm) | 1.553 | 1.656 | 1.904 | 2.131 | 2.318 | 2.572 | 2.691 |
| SD †             | 1.199 | 1.279 | 1.311 | 1.331 | 1.396 | 1.420 | 1.512 |
| p-values‡        | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

The anterior displacement was calculated as the difference in the tibiotalar distance based on the distance at 0 N.
Inter-examiner and inter-measurer reliability

We used the ICC(2,1) to assess the reliability of our new ultrasound-based method in the control group. The inter-examiner reliability for the ultrasound stress test was moderate \([\text{ICC}(2,1) = 0.690\text{ and } 0.639\text{ at } 120\text{ and } 150\text{ N, respectively}]\), and the inter-measurer reliability was excellent at 120 N \([\text{ICC}(2,1) = 0.923]\) and good at 150 N \([\text{ICC}(2,1) = 0.893]\) (Table 2). The 95% CI in the inter-measurer reliability was wider than that of the inter-examiner reliability. The 95% CI in the inter-examiner reliability suggested a wide range from approximately 0.2 to 0.8.

Table 2 Inter-examiner and inter-measurer reliability calculated by the intra-class coefficient ICC (2,1)

|               | Inter-examiner reliability | Inter-measurer reliability |
|---------------|----------------------------|----------------------------|
|               | ICC (2,1)                  | 95% CI                     | SEM * | CV † | MDC_{95} ‡ | ICC (2,1) | 95% CI | SEM * | CV † | MDC_{95} ‡ |
| 120 N         | 0.690                      | 0.291–0.857                | 0.235  | 0.614 | 0.615       | 0.923     | 0.840–0.962 | 0.211  | 0.559 | 0.584       |
| 150 N         | 0.639                      | 0.277–0.822                | 0.267  | 0.534 | 0.676       | 0.893     | 0.774–0.949 | 0.239  | 0.503 | 0.663       |

*SEM represents Standard Error of the Mean

†CV represents the Coefficient of Variation

‡MDC_{95} represents minimum detectable change at the 95% confidence level

Correlations between talar displacement values obtained from ultrasound and X-ray imaging

We next examined the correlations between the amounts of anterior displacement of the talus observed by ultrasound imaging with those observed by X-ray imaging in the control and AI groups. Because the measured values showed a normal distribution in both the control and AI groups, we used Pearson’s correlation coefficient for these comparisons. In the control group, there was a low correlation between the stress X-ray test and the ultrasound stress test at 120 N (, ), although there was a moderate correlation at 150 N (, ) (Fig. 7). In contrast, in the AI group, the stress X-ray test and ultrasound stress test showed a high correlation at 120 N (, ) and a moderate correlation at 150 N (, ; Fig. 8, Table 3).

Table 3 Correlation of the anterior talar shift of stress ultrasound and stress X-ray
Discussion

In the present study, we proposed a radiation-free method using stress ultrasound imaging and a Telos stress device to quantitatively evaluate mechanical instabilities following lateral ligament injury of the ankle.

The reliability of our new inspection method by the ICCs, i.e., ICC(2,1), between the two examiners and the two measurers at 120 N and 150 N were as follows: for inter-measurer reliability, ICCs indicated excellent reliability at 120 N and good reliability at 150 N within a narrow range of 95% CI (Table 2). These results suggested that the obtained images from this method fulfilled the practicality quality for measurement. However, although ICCs for inter-examiner reliability remained moderate at both 120 N and 150 N, the 95% CI indicated a wide range between 0.2 and 0.8 (Table 2). This might be due to not only the individual differences of the participants because of their healthy background, but also differences in the angle of the ultrasound probe. To overcome these problems, it might be necessary to determine the angle of insonation in the long axis to the Achilles tendon or skin surface, not only by visualization of the tibia and the medial tubercle of the posterior process of the talus. Furthermore, the additional landmark and other anatomical references might help to improve the reliability. The inspection ICCs at 120 N and 150 N showed excellent inter-measurer reliability. A firmer definition of the angle of insonation might lead to fixing the angle of the cortical bone border posterior extension line in the images. This might also improve the inter-measurer reliability.

We subsequently assessed a group of participants with ankle instability (AI group) and determined correlations between the amount of anterior displacement of the talus measured by the standard stress X-ray test (the conventional method) and the amount observed using ultrasound stress imaging. In the present study, to reduce the risk of radiation exposure as much as possible at the preliminary stage, we limited the small sample size. Due to this and the heterogeneity of the comparison groups, not all comparisons showed a significant correlation. However, the correlations were high at 120 N in the AI group.

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| Control group * | AI group† |
|-----------------|-----------|
| R‡ p-value§     | R‡ p-value§ |
| 120 N 0.206 0.408 | 0.722 0.043* |
| 150 N 0.425 0.130 | 0.491 0.217 |

*Control group: CAIT scores ≥ 25 points.

†AI group: CAIT scores < 25 points.

‡R represents Pearson's correlation.

§The value indicates a statistically significant value of $p < 0.05$
group. The reason it did not show the highest correlation at 150 N is thought to be a self-defense reaction caused by stress overload. Tohyama et al. suggested that 150 N produces muscular contraction around the ankle because of an excessively high anterior load [35]. Furthermore, they suggested that an anterior drawing force of 60 N is sufficient to evaluate significant differences in ligament elongation, as overload forces lead to stagnation of the elongation rate owing to defensive reactions from the participant [35]. The values of the present results were almost in line with their suggestions (Fig. 6 and Table 1). Although 150 N is the standard stress used to detect ankle instability with a Telos device, this load stress is physically quite severe for some participants. Therefore, here we also measured at 120 N to confirm the diagnostic effect of this method using a weaker stress than 150 N. In the control group, no significant correlation between the methods at 120 N was observed ($R = 0.206, p = 0.408$). A moderate, albeit insignificant, correlation was observed at 150 N ($R = 0.425, p = 0.130$) with Pearson's correlation coefficient (Fig. 7, Table 3). In contrast, stress ultrasound and stress X-ray of the AI group showed high, significant correlations using Pearson's correlation coefficient at 120 N ($R = 0.722, p = 0.043$) and moderate, insignificant correlations at 150 N ($R = 0.491, p = 0.217$) (Fig. 8, Table 3). Although the present study has limitations with regard to the participants in that we did not view ATFL injury by MRI or other diagnoses, and we did not assess mechanical instability, the data for the AI group at 120 N suggest a significant correlation between the X-ray and ultrasound results. The $p$-value did not indicate significance at 150 N because more participants are probably needed. Further validation studies are required to determine the optimal stress load for ultrasound stress imaging.

Lee et al. assessed the accuracy of CAI diagnoses made using conventional stress X-ray imaging and ultrasound imaging by comparing ATFL length measurements made using a manual anterior drawer test or the anterior translation of stress radiography [14]. In this study, the correlations between stress ultrasound and stress X-ray imaging were higher than those reported in a previous study both in the control and AI groups. The method presented herein, which depends on the quantification of changes in tibiotalar distances, should display more reliability than measuring the elongation of the ATFL by imaging because the ATFL does not exhibit a unique shape. While the length of the ATFL depends on the shape and thickness of the ligament (e.g., a straight shape versus a bent shape), the tibiotalar distances based on bone–bone distances are very clear and simple. Although there are several problems to overcome mentioned above, this is the first study reporting a method for measuring tibiotalar distances rather than measuring the length of the ATFL during the anterior drawer test and clinically, our method could expect to simultaneously quantify ankle instability.

Additional to the improvement of the angle of insonation, in the future, it will be desirable to improve the positioning of the examinee and the method used to apply the anterior pulling force to further improve both the reliability between examiners and the correlation with X-ray stress imaging. In this study, plantarflexion and dorsiflexion of the palm posed a problem when applying the anterior pulling force. By developing an attachment (e.g., a fixture) to prevent such distortions, we believe that the anterior pulling force will directly lead to an increase in the amount of anterior displacement of the talus and will also help keep the posterior tibial angle constant during examination. Furthermore, it is also necessary to study
different imaging methods based on the visualization of the talus. Imaging from the anterior aspect of the ankle might be valuable to achieve more excellent and higher reliabilities and correlations, respectively.

We acknowledge that our study has some limitations. First, we did not assess ATFL injuries or mechanical instability. To overcome this limitation, we must recruit additional patients with ATFL injuries and compare their test results according to their injury severity scores. Second, we could not recruit participants with clinically diagnosed ankle instability.

This study is the first preliminary study to confirm the usefulness of this new ultrasound-based method for detecting anterior displacement of the talus during the anterior drawer stress test without radiation exposure. Although further investigations are essential, we here report the use of a new ultrasound-based method to detect increases in the distance between the tibia and the talus caused by the anterior displacement of the talus in response to stress. This new examination is expected to enable fixed-quantity evaluations of mechanical ankle instabilities using the same apparatus in the same examination room.

**Conclusions**

In the present study, we evaluated the reliability and validity of anterior talar displacement during the anterior drawer stress test using a new stress ultrasound examination combined with a Telos stress device for the quantitative detection of ankle instability, and whether the present examination could replace the conventional X-ray test. This stress ultrasound imaging has the potential for clinical application to quantitatively evaluate mechanical instability with a radiation-free method.

**Declarations**

**Ethics approval and consent to participate**

This research was approved by the Hokkaido University Graduate School of Health Sciences Ethics Application Committee (approval number: 18–59). Sufficient explanation was given to the subjects, and all experiments were carried out after obtaining the consent by signing the consent form from all subjects.

**Consent for publication**

Not Applicable.

**Availability of data and materials**

The data that support the findings of this study are not publicly available. Data are however available from the authors upon reasonable request.

**Competing interests**

The authors declare that they have no competing interests.
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Nothing to declare.

Authors’ contributions

Conception and design: KT and HT; Data analysis and interpretation: UN, MT, MT and TH; Collection and assembly of data: UT, KM, MT, MT and MY; Drafting the article or revising it: UN, YK, TH, MS, KT, TM and HT; All authors read and approved the final manuscript.

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Figures
Figure 7

Correlation in control group between the amounts of anterior talar displacement measured from stress ultrasound images and stress X-ray images at 120 and 150 N. The control group had CAIT scores ≥ 25 points.