

# The Relationship Between the Distal Tibial Fibular Syndesmosis and the Varus Deformity in Patients With Varus Ankle Osteoarthritis

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## Abstract

**Background:** The impact of varus ankle osteoarthritis (OA) on the distal tibial fibular syndesmosis is poorly described. This study aimed to investigate the possible relationship between the condition of the distal tibial fibular syndesmosis and the degree of the varus deformity using weightbearing simulated computed tomography (CT), in patients with varus ankle OA.

**Methods:** This retrospective comparative study included 155 varus ankles, divided into 4 Takakura-Tanaka groups (stage 2, 3a, 3b, and 4). A control group comprised 35 ankles without prior ankle disorders. The angles between the tibial shaft and the articular surface of the tibial plafond on the anteroposterior view (TAS), and articular surfaces of the tibial plafond and talar dome (TTW) were measured from weightbearing ankle radiographs. The varus angle of the ankle (VA) was defined as  $90 - \text{TAS} + \text{TTW}$ . On the CT axial view, 1 cm proximal to the tibial plafond, the area of the syndesmosis ("CT-area") and the distance between the fibula and the tibia (CT-FCS) were measured.

**Results:** The CT area in stages 2, 3a, 3b, 4, and control group were 99, 79, 77, 103, and 97 mm<sup>2</sup>, respectively. The CT-FCS were 3.5, 3.1, 2.9, 4.3, and 3.9 mm, respectively. In all 155 OA ankles, CT area and CT-FCS were negatively correlated with the VA (correlation coefficient  $r = -0.38$ ,  $P < .01$ ; and  $r = 0.38$ ,  $P < .01$ , respectively). Both CT area and CT-FCS were significantly smaller in stages 3a and 3b than in the control group ( $P < .01$ ).

**Conclusion:** There may be a relationship between the narrowing of the syndesmosis and the varus deformity in patients with varus ankle OA, especially in stages 3a and 3b.

**Clinical Relevance:** Clinicians should be aware of the impact of varus ankle arthritis on the distal tibial fibular syndesmosis when operatively treating varus ankle OA. For some patients, the isolated treatment for the tibiotalar joint may be insufficient, and treatment for the syndesmosis as well as tibiotalar joint may be needed.

**Level of Evidence:** Level III, retrospective case control study.

**Keywords:** varus ankle osteoarthritis, syndesmosis, etiology

## Introduction

Ankle osteoarthritis (OA) affects approximately 6% of the population.<sup>7</sup> Functional disability and the diminished quality of life associated with end-stage ankle OA are reportedly comparable to those associated with end-stage hip or knee OA.<sup>2,12</sup> The most common cause of ankle OA is intra-articular fracture.<sup>4,14</sup> Varus ankle OA with no history of trauma or general disorder is rare. However, in Japan, varus ankle OA is the most common type attributed to the Japanese lifestyle, in which people sit cross-legged or with their legs tucked underneath the body.<sup>15</sup> Radiologic

examinations of varus ankle OA have shown a characteristic varus deformity combined with anterior opening of the tibiotalar joint and, often, hypoplasia of the medial malleolus. A previous study on the etiology of varus ankle OA mainly

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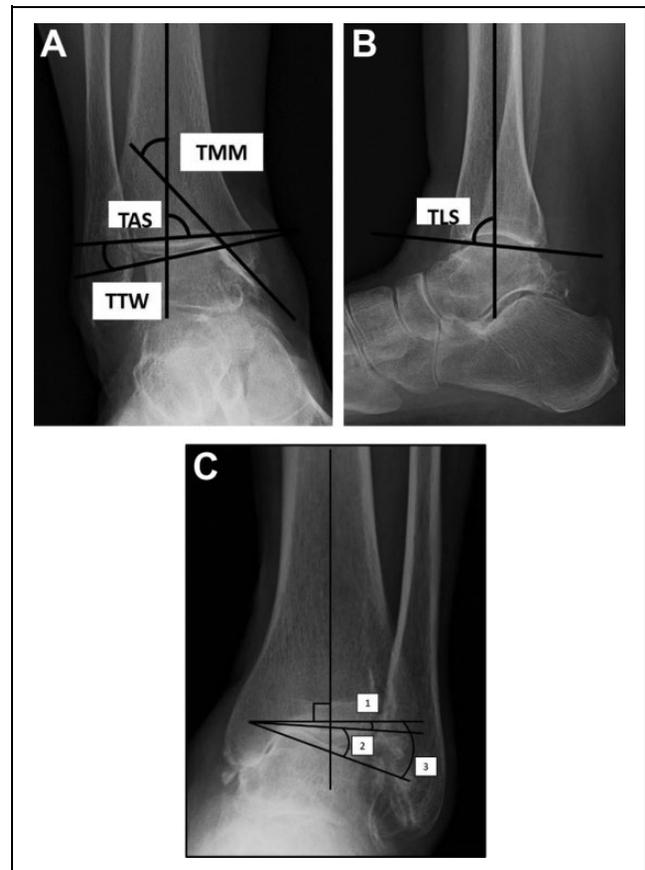
**Figure 1.** Three radiographic parameters have been used in the diagnosis of syndesmosis: (A) tibiofibular overlap, (B) tibiofibular clear space, and (C) medial clear space.

reported on the instability of the lateral ankle ligaments such as anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL).<sup>6</sup> Although some reports have reported the relationship between syndesmotic injury and traumatic ankle arthritis, the syndesmosis in patients with varus OA has not been investigated in detail.

The syndesmosis was traditionally evaluated with 3 radiographic parameters: tibiofibular overlap, tibiofibular clear space, and medial clear space (Figure 1).<sup>3,5,13,18</sup> However, the radiographic parameters were affected by the ankle position relative to the X-ray beam.<sup>3,5,13,18</sup> Recently, a few computed tomography (CT) parameters were found to be able to evaluate the syndesmosis clearly.<sup>1</sup> In this study, the syndesmosis was evaluated by CT scan with axial loading using a DynaWell L-spine compression device (DynaWell Inc., Las Vegas, NV) to simulate the weightbearing condition.<sup>8,9,11</sup> The purpose of this study was to evaluate the syndesmosis in patients with varus ankle OA using CT. The relationship between the syndesmosis and the varus deformity was investigated.

## Material and Methods

From January 2012 to December 2018, a consecutive 155 ankles from 126 patients diagnosed with varus ankle OA and treated either conservatively or surgically were investigated in this study. Angles between the tibial shaft and articular surface of the tibial plafond on the anteroposterior and lateral views (TAS and TLS), tibial shaft and medial malleolus (TMM), and articular surfaces of the tibial plafond and talar dome (TTW) were measured using weightbearing ankle



**Figure 2.** (A) The angles between the tibial shaft and the articular surface of the tibial plafond (TAS), tibial shaft and the medial malleolus (TMM), and the articular surfaces of the tibial plafond and talar dome (TTW) were measured from weightbearing anteroposterior ankle radiography. (B) The angle between the tibial shaft and articular surface of the tibial plafond (TLS) was measured using weightbearing lateral ankle radiography. (C) The varus angle of the ankle (VA) was defined as  $90 - \text{TAS} + \text{TTW}$ . 1:  $90 - \text{TAS}$ ; 2: TTW; 3:  $90 - \text{TAS} + \text{TTW}$  (VA).

radiographs (Figure 2A and B). In this study, the varus angle of the ankle (VA) was defined as  $90 - \text{TAS} + \text{TTW}$  (Figure 2C), and varus ankle OA was defined as VA of  $>0$ . The data were collected from patient records. Both admitted patients and outpatient department patients were included. Patients with traumatic ankle arthritis and with general disorders, such as rheumatoid arthritis or Charcot neuroarthropathy, were excluded from the study. Diagnosis was made using conventional weightbearing ankle radiography for all patients, who were then graded using the Takakura-Tanaka classification.<sup>16</sup> Stage 2 group included narrowing of the ankle space, stage 3a group included obliteration of the ankle space limited to the facet of medial malleolus with subchondral bone contact, stage 3b group included limited obliteration of the ankle space with subchondral bone contact extended to the roof of the dome of the talus, and stage 4 group included the obliteration of more than 50% of the joint space with complete bone contact (Figure 3). The control group included patients without prior



**Figure 3.** Takakura-Tanaka classification stages (A) 2, (B) 3a, (C) 3b, and (D) 4.

**Table 1.** Patient Background.

	n	Age
Control	35	47 ± 18
Stage 2	11	64 ± 11
Stage 3a	28	68 ± 8.0
Stage 3b	65	68 ± 9.0
Stage 4	51	69 ± 7.3

ankle injuries or disorders, such as bone tumor. In most patients with trauma and tumor, uninjured and unaffected ankles were evaluated by CT to compare the injured and affected sides. Patients in the control group were selected either conservatively or surgically for bone tumor and trauma in the same period. The contralateral side of the bone tumor or trauma side was evaluated as the control ankle. Weightbearing simulated CT with axial loading using a DynaWell L-spine compression device was performed in our institution starting in October 2011. Study subjects were placed in a supine position on the cradle, and pressure was applied from the plantar side using a dedicated plastic board with an adjustment mechanism. The amount of pressure was determined to be 300 N according to the instrument manual.<sup>8,9,11</sup> The patients in groups stage 2, stage 3a, stage 3b, stage 4, and controls included 11, 28, 65, 51, and 35 ankles, respectively. The average ages were 64 ± 11, 68 ± 8.0, 68 ± 9.0, 69 ± 7.3, and 47 ± 18 years, respectively (Table 1). On the axial CT view, at a level 1 cm proximal to the lateral side of the tibial plafond, the space between the lateral cortex of the tibial incisura and the medial cortex of the lateral malleolus, and 2 lines tangential to the anterior and posterior aspects of the tibia and fibula were measured as the syndesmotic area (CT-area) (Figure 4A and B).<sup>1</sup> Abdelaziz et al<sup>1</sup> evaluated the intra- and interobserver reliability of syndesmotic reduction on weightbearing CT scan, and concluded that the CT area demonstrated the highest reliability. On the axial CT view, at a level 1 cm proximal to the lateral side of the tibial plafond, the connecting line between the medial tibial edge and the lateral fibular

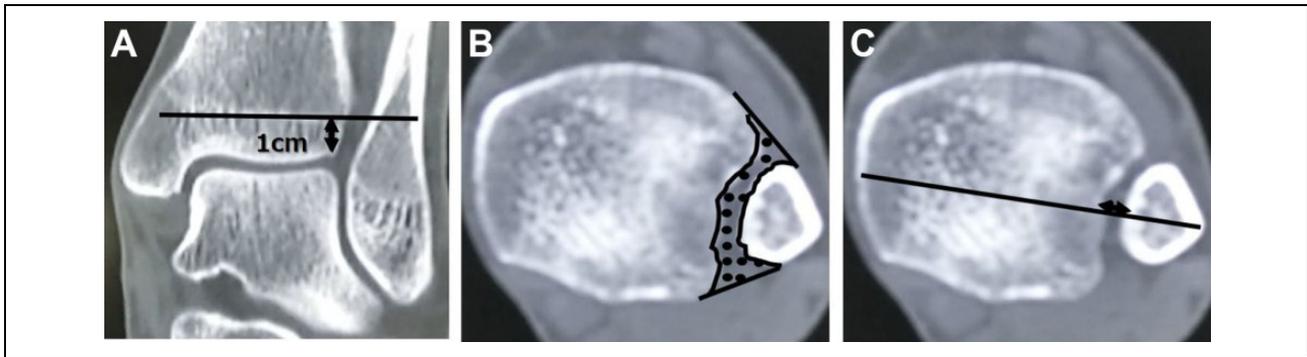
edge was designated. The distance between the medial fibular edge and lateral tibial edge on that line was measured as the fibular clear space (CT-FCS) (Figure 4C). All measurements in this study were performed by one of the authors (an orthopedic foot surgeon trained for >20 years).

### Statistical Analysis

First, the normal distribution of data was checked with the *F* test. After the data were confirmed to be normally distributed, Tukey-Kramer tests were used to compare each group. Pearson correlation was used for all ankles regardless of each group. A *P* value <.05 was considered significant. All statistical analyses were carried out using Statcel 3 (version 3; OMS, Tokyo, Japan). Based on the sample size calculation, Pearson correlation analysis requires 194 ankles to reach an adequate power.

### Results

The TAS measurements in the groups stage 2, stage 3a, stage 3b, stage 4, and the controls were 87 ± 3.9, 83 ± 2.5, 82 ± 3.6, 80 ± 5.9, and 87 ± 2.2 degrees, respectively. The TLS measurements were 78 ± 2.8, 79 ± 3.8, 77 ± 8.4, 75 ± 6.4, and 80 ± 2.1 degrees, respectively. The TMM measurements were 31 ± 8.7, 44 ± 9.5, 51 ± 1.3, 45 ± 1.3, and 29 ± 5.6 degrees, respectively. The TTW measurements were 1.2 ± 2.0, 5.7 ± 4.3, 12 ± 5.2, 0.29 ± 1.3, and 0.12 ± 0.48 degrees, respectively. VA measurements were 3.2 ± 2.3, 4.4 ± 4.7, 13 ± 5.0, 20 ± 6.4, and 9.9 ± 6.1 degrees, respectively. The CT area measurements were 99 ± 20, 79 ± 19, 77 ± 20, 103 ± 21, and 97 ± 18 mm<sup>2</sup>, respectively. The CT-FCS measurements were 3.5 ± 0.88, 3.1 ± 1.0, 2.9 ± 1.2, 4.3 ± 1.7, and 3.9 ± 1.1 mm, respectively (Table 2, Figure 5). In all the ankle OA groups, CT area and CT-FCS correlated negatively with TMM and VA (Figure 6). CT area and CT-FCS in stage 3a and 3b were significantly smaller than those in the control group. However, there were no significant differences in CT area and CT-FCS between stage 3a



**Figure 4.** (A) The axial CT view, at a level 1 cm proximal to the lateral side of the tibial plafond. (B) CT area: the space between the lateral cortex of the tibial incisura, the medial cortex of the lateral malleolus, and 2 lines tangential to the anterior and posterior aspects of the tibia and fibula. (C) CT-FCS: the distance between the medial fibular edge and lateral tibial edge was measured.

**Table 2.** Parameters in Each Group.

	TAS	TLS	TMM	TTW	VA	CT Area	CT-FCS
Control	87 ± 2.2	78 ± 2.8	29 ± 5.6	0.12 ± 0.48	3.2 ± 2.3	97 ± 18	3.9 ± 1.1
Stage 2	87 ± 3.9	79 ± 3.8	31 ± 8.7	1.2 ± 2.0	4.4 ± 4.7	99 ± 20	3.5 ± 0.88
Stage 3a	83 ± 2.5	77 ± 8.4	44 ± 9.5	5.7 ± 4.3	13 ± 5.0	79 ± 19	3.1 ± 1.0
Stage 3b	82 ± 3.6	75 ± 6.4	51 ± 13	12 ± 5.2	20 ± 6.4	77 ± 20	2.9 ± 1.2
Stage 4	80 ± 5.9	80 ± 2.1	45 ± 13	0.29 ± 1.3	9.9 ± 6.1	103 ± 21	4.3 ± 1.7

Abbreviations: CT area, the space between the lateral cortex of the tibial incisura, the medial cortex of the lateral malleolus, and 2 lines tangential to the anterior and posterior aspects of the tibia and fibula; CT-FCS, the distance between the medial fibular edge and lateral tibial edge measured as the fibular clear space; TAS, angle between the tibial shaft and articular surface of the tibial plafond on the anteroposterior view; TLS, angle between the tibial shaft and articular surface of the tibial plafond on the lateral view; TMM, angle between the tibial shaft and medial malleolus; TTW, angle between articular surfaces of the tibial plafond and talar dome; VA, varus angle of the ankle.

and 3b. The TMM and the TTW in stages 3a and 3b were significantly larger than those in the control group, and the TMM and TTW in stage 3b were also significantly larger than those in stage 3a.

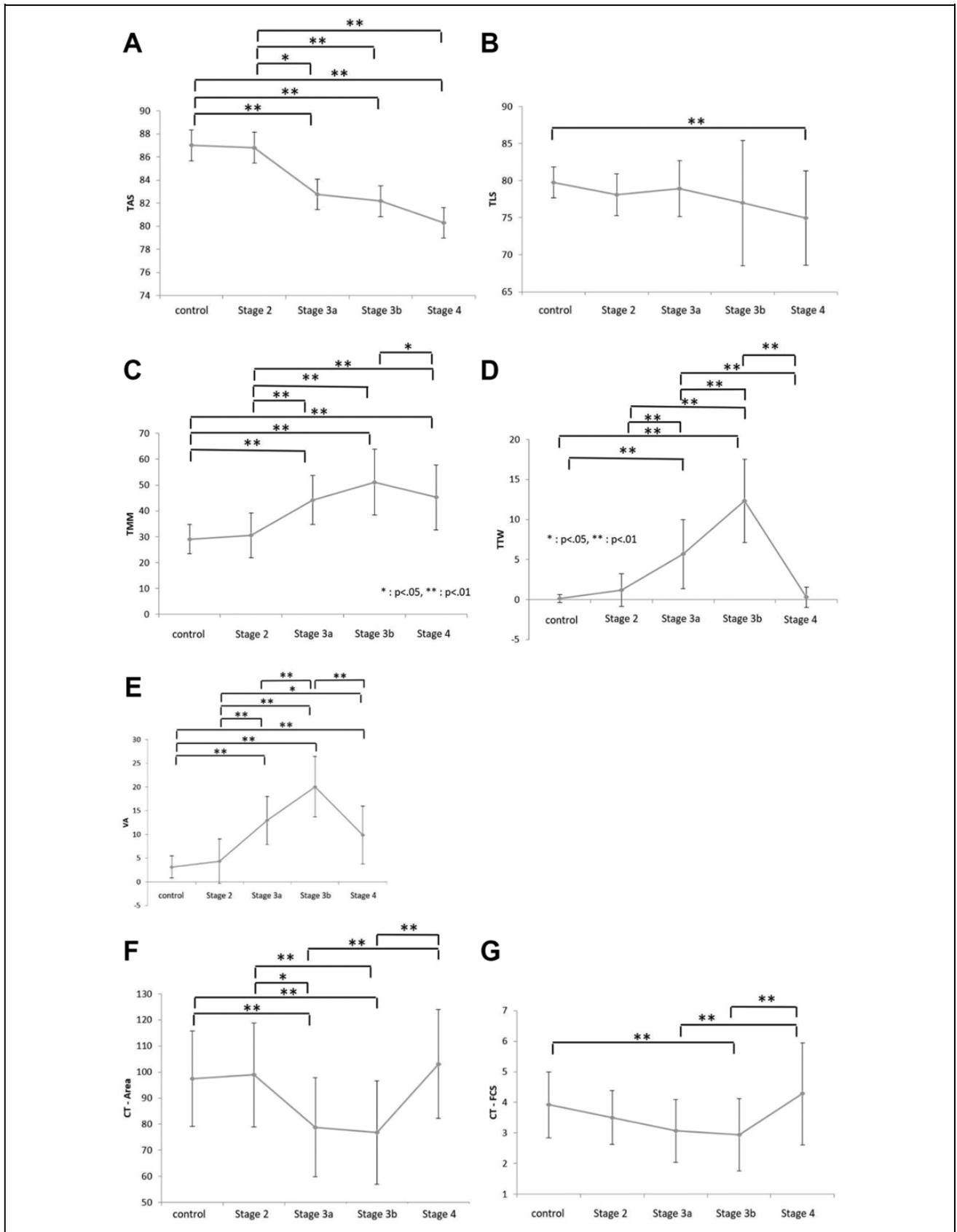
## Discussion

Harrington<sup>6</sup> reported that 10 years after the diagnosis of lateral ligament insufficiency, 77% of the patients investigated had ankle OA. Since his report, a few reports have concluded that one of the major causes of ankle OA, particularly on the medial side, is chronic lateral instability of the ankle.<sup>10</sup>

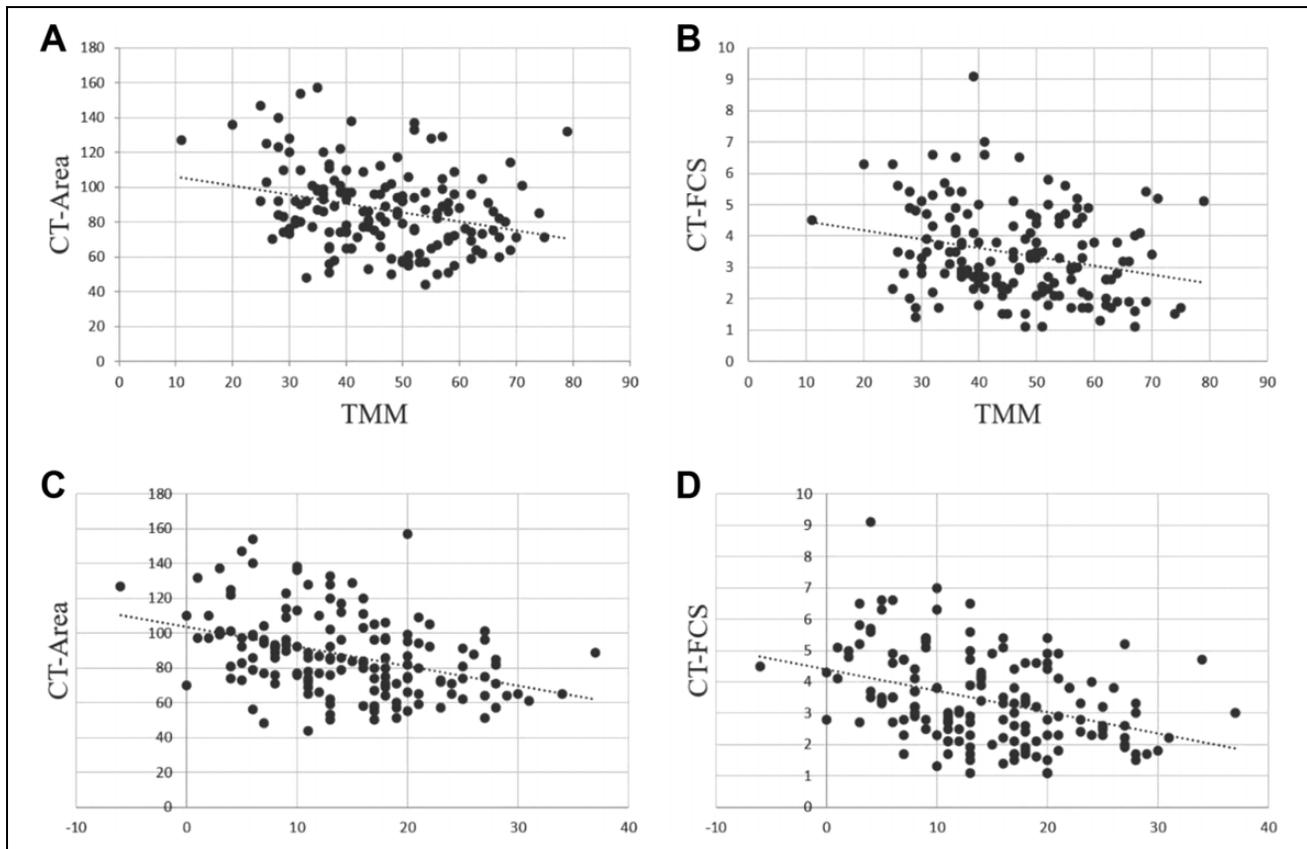
The syndesmosis is defined as a fibrous joint in which the tibia and the fibula are linked by 4 ligaments; it contributes to ankle stability.<sup>7</sup> Ligamentous structures in the distal portion of the syndesmosis have 3 major components. The anterior aspect consists of the anterior inferior tibiofibular ligament, the middle aspect consists of the interosseous ligament, and the posterior aspect consists of the posterior inferior tibiofibular and transverse ligaments.<sup>2</sup> A cadaveric study concluded that the anterior inferior tibiofibular, interosseous, and posterior inferior tibiofibular ligaments contribute to 35%, 22%, and 42% of syndesmosis stability, respectively, and rupture of more than 1 component endangers

syndesmosis stability.<sup>12</sup> Although the syndesmosis is a joint, many previous studies tend to mention syndesmosis ligaments and have concluded that syndesmosis instability owing to the dysfunction of the syndesmosis ligaments causes cartilage damage in the tibiotalar joint in patients with traumatic ankle arthritis.<sup>17</sup> However, the relationship between the syndesmosis and varus ankle OA has received relatively little attention. In this study, the syndesmosis was evaluated in patients with varus ankle OA, and the relationship between the syndesmosis and the varus deformity was reported.

The syndesmosis has been evaluated using conventional radiographic images traditionally. However, the radiographic parameters are affected by the ankle position relative to the X-ray beam.<sup>3,5,13,18</sup> Accordingly, Abdelaziz et al<sup>1</sup> reported intra- and interobserver reliability for evaluating the syndesmosis radiographically between the 2 observers. In their report, the distance between the middle of the incisura and the nearest point of the fibula (similar to the CT-FCS in our study), and the syndesmosis area calculation, which was referred to as CT area in this study, were confirmed as the most reliable evaluation methods. In this study, the syndesmosis was measured using CT-FCS and CT area at a defined ankle position. CT with axial loading using a DynaWell compression device was suitable for simulating



**Figure 5.** Distribution in each group. (A) TAS, (B) TLS, (C) TMM, (D) TTW, (E) VA, (F) CT-Area, (G) CT-FCS.



**Figure 6.** Correlation in each group. (A) CT Area and TMM, (B) CT-FCS and TMM, (C) CT-Area and VA, (D) CT-FCS and VA.

weightbearing to evaluate the syndesmotic condition.<sup>8,9,11</sup> The results of these previous studies validate the methods used in this study.

In all the 155 OA ankles, CT area and CT-FCS were negatively correlated with the VA (correlation coefficient  $r = -0.38$ ,  $P < .01$ , and  $r = -0.38$ ,  $P < .01$ , respectively). They were also negatively correlated with the TMM ( $r = -0.29$ ,  $P < .01$ , and  $r = -0.25$ ,  $P < .01$ , respectively). The main reason for the small CT area and CT-FCS was osteophyte formation at the syndesmosis. OA change at the syndesmosis prevented anatomic motion. Because of worsening lateral instability, the concentration of the weight load occurred on the medial ankle side. The degree of the varus deformity was represented by the VA and the TMM. Thus, from these results, syndesmotic OA likely correlated to varus deformity in patients with ankle OA.

Between groups, the CT area in the stage 3a and 3b groups was significantly smaller than that in the control group. Similarly, the CT-FCS in stage 3b group was significantly smaller than that in the control group. There were no significant differences in the CT area and CT-FCS between stage 3a and stage 3b groups. VA in stage 3b group was larger than that in the stage 3a group. The osteophyte at the syndesmosis caused small CT area and small CT-FCS. Syndesmotic OA especially occurred in stage 3a and 3b groups. Lateral instability and syndesmotic OA made the load

concentrate medially at the ankle and may be related to varus deformity. Thus, one of the most important etiologies in stage 3a and 3b groups was concluded with syndesmotic OA from this study.

There were no significant differences in the CT area and CT-FCS between stage 4 group and controls. VA in stage 4 group was significantly larger than that in the control group; however, it was significantly smaller than that in the stage 3b group. The TLS in stage 4 group was significantly smaller than that in the controls. In the stage 4 group, various patients seem to be combined. This included patients with varus deformity with syndesmotic OA and the patients retaining the alignment without syndesmotic OA.

A limitation of this study was that consecutive 190 ankles were investigated; thus, the number and the average ages of patients in each group were not matched sufficiently. Based on the sample size calculation, as mentioned in the Materials and Methods section, Pearson correlation analysis requires 194 ankles to reach an adequate power. Measurements were performed once by one surgeon alone. However, the reliability of CT area and CT-FCS has already been reported.<sup>1</sup> Second, some studies reported the availability of the DynaWell<sup>8,9,11</sup>; however, the DynaWell does not completely simulate the ankle in the standing position. Finally, as this was a cross-sectional study, the relationship between syndesmotic OA and varus deformity in patients with varus

ankle OA was demonstrated. However, the order of their occurrence cannot be concluded in this study. Therefore, further basic or longitudinal studies may be required to verify our findings.

To conclude, this study revealed that the syndesmotic condition was related to the varus deformity in patients with ankle OA. OA at the syndesmosis prevented the anatomical motion, and may cause varus deformity, especially stage 3a and 3b. The lateral ligament instability and varus inclination of the tibial plafond were the triggers for ankle OA, and syndesmotic OA may cause progression of the varus deformity. However, to our knowledge, this is the first article to reveal the relationship between the syndesmosis and varus deformity in patients with ankle OA.

### Ethics Approval

This research was approved by the institutional review board of our affiliated institutions (IRB No. 848). An opt-out statement for the application of the medical data was published on the website of our institute. The study was performed in accordance with the principles laid down by the World Medical Association Declaration of Helsinki.

### 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.

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### References

1. Abdelaziz ME, Hagemeyer N, Guss D, et al. Evaluation of syndesmosis reduction on CT scan. *Foot Ankle Int.* 2019; 40(9):1087-1093.
2. Bartonicek J. Anatomy of the tibiofibular syndesmosis and its clinical relevance. *Surg Radiol Anat.* 2003;25(5-6):379-386.
3. Beumer A, van Hemert WLW, Niesing R, et al. Radiographic measurement of the distal tibiofibular syndesmosis has limited use. *Clin Orthop Relat Res.* 2004;423:227-234.
4. Buckwalter JA, Saltzman CL. Ankle osteoarthritis: distinctive characteristics. *Instr Course Lect.* 1999;48:233-241.
5. Harper MC, Keller TS. A radiographic evaluation of the tibiofibular syndesmosis. *Foot Ankle.* 1989;10(3):156-160.
6. Harrington KD. Degenerative arthritis of the ankle secondary to long-standing lateral ligament instability. *J Bone Joint Surg Am.* 1979;61(3):354-361.
7. Hermans JJ, Beumer A, de Jong TAW, et al. Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach. *J Anat.* 2010;217(6):633-645.
8. Hioki A, Miyamoto K, Sakai H, et al. Lumbar axial loading device alters lumbar sagittal alignment differently from upright standing position: a computed tomography study. *Spine (Phila Pa 1976).* 2010;35(9):995-1001.
9. Hioki A, Miyamoto K, Shimizu K, et al. Test-retest repeatability of lumbar sagittal alignment and disc height measurements with or without axial loading: a computed tomography study. *J Spinal Disord Tech.* 2011;24(2):93-98.
10. Hirose K, Murakami G, Minowa T, et al. Lateral ligament injury of the ankle and associated articular cartilage degeneration in the talocrural joint: anatomic study using elderly cadavers. *J Orthop Sci.* 2004;9(1):37-43.
11. Iwata T, Miyamoto K, Hioki A, et al. In vivo measurement of lumbar foramen during axial loading using a compression device and computed tomography. *J Spinal Disord Tech.* 2013;26(5):E177-E182.
12. Ogilvie-Harris D, Reed S. Disruption of the ankle syndesmosis: diagnosis and treatment by arthroscopic surgery. *Arthroscopy.* 1994;10(5):561-568.
13. Pneumaticos SG, Noble PC, Chatziioannou SN, et al. The effects of rotation on radiographic evaluation of the tibiofibular syndesmosis. *Foot Ankle Int.* 2002;23(2):107-111.
14. Saltzman CL, Salamon ML, Blanchard GM, et al. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. *Iowa Orthop J.* 2005;25:44-46.
15. Takakura Y, Tanaka Y, Kumai T, et al. Low tibial osteotomy for osteoarthritis of the ankle. Results of a new operation in 18 patients. *J Bone Joint Surg Br.* 1995;77(1):50-54.
16. Tanaka Y, Takakura Y, Hayashi K, et al. Low tibial osteotomy for varus-type osteoarthritis of the ankle. *J Bone Joint Surg Br.* 2006;88(7):909-913.
17. Wagener ML, Beumer A, Swierstra BA. Chronic instability of the anterior tibiofibular syndesmosis of the ankle. Arthroscopic findings and results of anatomical reconstruction. *BMC Musculoskelet Disord.* 2011;12(1):212.
18. Zalavras C, Thordarson D. Ankle syndesmotic injury. *J Am Acad Orthop Surg.* 2007;15(6):330-339.