

# Four-Dimensional CT Analysis of Ankle Motion and Syndesmosis in Ankle Osteoarthritis

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## INTRODUCTION:

The tibiofibular syndesmosis plays an important role in ankle stability; and the distal tibiofibular joint shows motion throughout the ankle range of motion (ROM), as well as in response to loading. The relationship between tibiofibular syndesmosis and ankle osteoarthritis (AOA) has been reported in various studies, but it remains unclear. Previously, evaluation of the ankle joint has involved static evaluation using computed tomography (CT) or dynamic evaluation using fluoroscopy. However, CT and fluoroscopy fails to evaluate the ankle joint, according to its movement and in three dimensions, respectively. Four-dimensional CT (4DCT), also known as dynamic CT, is an emerging technology that can image a joint in real time as it moves through ROM and accurately capture changes in syndesmotic position with ankle ROM. The study aimed to use 4DCT to investigate the effect of ankle ROM on syndesmosis and dynamics of rotational motion in AOA patients.

## METHODS:

This study included patients with ankle osteoarthritis and healthy adult volunteers, who gave consent for the study starting in February 2021. They were classified into two groups: AOA and control groups. The control group had ankles with no history of fracture or degenerative disease. Each participant underwent a 4DCT of their unilateral or bilateral ankles. Two patterns of motion were performed with 8 seconds: positive motion for dorsal-plantar flexion, and passive motion for internal-external rotation. Computed tomography dose index per exposure was 1.0 mGy, and the stress operator was under radiation protective clothing. Syndesmotic measurements were taken 10 mm above the plafond. These measurements included anterior (ASD), middle (MSD), and posterior (PSD) syndesmotic distances, which were measured from the most anterior and posterior points of the incisura, as well as the midpoint of the incisura, to the closest corresponding points on the fibula (Figure.1). Fibular rotation was defined as the angle between the fibular axis and the incisura tangent. The syndesmotic area was determined by fitting tangents between the tibia and fibula anteriorly and posteriorly and subsequently finding the area bounded by the tangents. Each parameter was evaluated at neutral position, maximum dorsal flexion, plantar flexion, internal rotation, and external rotation. Comparisons were made between AOA and control groups. In addition, the angle between the axis of the tibia and the axis of the talus in axial view during internal and external rotation was used as the tibiotalar rotation angle (TTRA) to evaluate the rotational instability of the talus. OA progression was classified according to the Takakura-Tanaka classification and evaluated for syndesmosis and rotational instability at each stage (Figure.2).

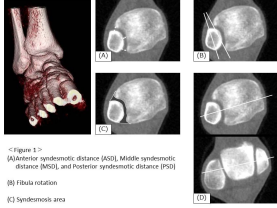
## RESULTS:

Twenty-eight ankles were included in the analysis. Eighteen ankles were from the AOA group and 10 were from the control group. The mean age was 59.1 (range, 26-87) years. In AOA group, in neutral position, the mean ASD, MSD, and PSD were 2.6 mm, 3.2 mm, and 6.4 mm, respectively. Syndesmotic area in neutral position was 122 mm<sup>2</sup>, decreased by 3.3 mm<sup>2</sup> during dorsiflexion to plantarflexion, and increased by 5.2 mm<sup>2</sup> during internal rotation to external rotation (Table.1). In Control group, in neutral position, the mean ASD, MSD, and PSD were 2.0 mm, 2.3 mm, and 5.2 mm, respectively. Syndesmotic area was 101 mm<sup>2</sup>; significantly smaller than in AOA group. It decreased by 24.8 mm<sup>2</sup> during dorsiflexion to plantarflexion, and increased by 8.6 mm<sup>2</sup> during internal rotation to external rotation.

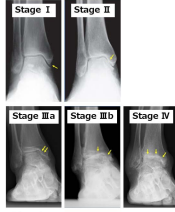
According to the Takakura-Tanaka classification, five cases were at stage 3a, seven cases were at stage 3b, and six cases were at stage 4. Internal/external TTRA was 21.4°/-0.3° in stage 3a, 19.0°/-4.5° in stage 3b, 12.1°/0.8° in stage 4, and 12.1°/1.3° in the control group (Table.2).

## DISCUSSION AND CONCLUSION:

This study showed that the distance and area of the tibiofibular syndesmosis were greater in the AOA group than in the control group; however, the amount of change in the syndesmosis with ankle motion was greater in the control group. In the AOA group, the syndesmosis may have failed due to advanced degeneration, while the changes with ankle motion may have been smaller due to osteophytes and decreased ROM. In stages 3a and 3b, which had strong internal deformity, the range of motion for internal rotation was large, whereas that for external rotation was small. In stage 4, the joints became narrower throughout the mortise, the range of motion for internal and external rotation was close to that of the control group, suggesting that the pathophysiology of this stage is different from that of stages 3a and 3b. This study may provide important information to understand the pathogenesis of ankle osteoarthritis.



< Figure 1 >  
 (A) Anterior syndesmosis distance (ASD), Middle syndesmosis distance (MSD), and Posterior syndesmosis distance (PSD)  
 (B) Fibula rotation  
 (C) Syndesmosis area  
 (D) Tibiotalar rotation angle (TTRA)



< Figure 2 >  
 Takuzo-Tanaka classification:  
 Stage I: no narrowing of the joint space, but early sclerosis and formation of osteophytes;  
 Stage II: narrowing of the medial joint space;  
 Stage III: obliteration of the space with subchondral bone contact  
 (a) obliteration of the joint space is limited to the medial malleolus  
 (b) the obliteration extends to the roof of the dome of the tibia  
 Stage IV: obliteration of the whole joint space with complete bone contact

AOA group	Mean						
	Neutral	Dorsal	Plantar	Int rot	Ext rot	Dorsal to plantar	Int rot to ext rot
ASD, mm	2.6	2.6	2.5	2.4	2.4	-0.13	+0.07
MSD, mm	3.2	3.0	3.0	3.3	3.6	-0.04	+0.35
PSD, mm	6.4	6.0	5.9	6.2	6.3	-0.12	+0.09
Fibular rot, °	8.3	7.2	7.1	7.0	7.5	-0.05	+0.59
Syndesmosis area, mm <sup>2</sup>	122.0	122.2	118.9	125.0	130.2	-3.3	+5.2

Control group	Mean						
	Neutral	Dorsal	Plantar	Int rot	Ext rot	Dorsal to plantar	Int rot to ext rot
ASD, mm	2.0	2.6	2.1	1.9	3.0	-0.52	+1.2
MSD, mm	2.3	3.1	2.0 <sup>a</sup>	2.7	3.0	-1.0 <sup>b</sup>	+0.27
PSD, mm	5.2 <sup>a</sup>	5.4	4.5 <sup>b</sup>	5.3	4.9 <sup>b</sup>	-0.92 <sup>b</sup>	-0.39
Fibular rot, °	8.1	8.5	8.4	7.9	8.1	-0.03	+0.19
Syndesmosis area, mm <sup>2</sup>	101.3 <sup>a</sup>	113.3	88.5 <sup>b</sup>	104.9 <sup>b</sup>	113.5	-24.8 <sup>b</sup>	+8.6

< Table 1 >  
 Measurements for the AOA group and the Control group are shown, in the ankle positions: neutral, dorsiflexion (dorsal), plantarflexion (plantar), internal rotation (int rot), external rotation (ext rot).  
 "Dorsal to plantar" and "int rot to ext rot" indicate the amount of change.  
 (a) p < 0.05 versus AOA group

	N	Syndesmosis area, mm <sup>2</sup>			TTRA, °	
		Neutral	Dorsal to plantar	Int rot to ext rot	Internal	External
Normal	10	101.3	-24.8	+8.6	12.1	1.3
Stage 3a	5	123.4	-4.6	+10.0	21.4	-0.28
Stage 3b	7	112.3	-1.6	+0.67	19.0	-4.5
Stage 4	6	132.2	-4.2	+6.5	12.1	0.82

< Table 2 >  
 Syndesmosis area and tibiotalar rotation angle (TTRA) for each OA stage are shown.