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Alignment of Ankle and Hindfoot in Early Stage Ankle Osteoarthritis

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ABSTRACT

Background: **Supramalleolar osteotomy has been recommended to correct varus deformity of the tibial plafond; however, we have seen only a few ankles with significant deviation of alignment in early stage osteoarthritis, in which realignment treatments might be necessary to modify the course of the disease. Our hypothesis was that there are diverse radiographic features of the tibial plafond and hindfoot in varus ankle osteoarthritis.** ***Materials and Methods:*** **The study included 154 ankles of 98 patients with medial osteoarthritis, and 80 ankles of 80 normal subjects. On weightbearing AP radiographs, the tibial anterior surface angle (TAS), tibial axis-medial malleolus angle (TMM) and talar tilt angle was measured. On weightbearing lateral radiographs, tibial lateral surface angle (TLS) was measured. On the hindfoot alignment view, the heel alignment angle and heel alignment ratio were obtained. Inter- and intraobserver reliabilities were obtained for all radiographic parameters. The radiographic parameters were compared among the normal ankles and the ankles in different stages of ankle arthritis by the Takakura classification.** ***Results:*** **Inter- and intraobserver reliability were very high for all radiographic parameters except TLS. There was no statistically significant difference in TAS among Stages 2, 3a, and 3b. TAS was 86.9 ± 2.4 degrees, 86.2 ± 3.3 degrees, and 85.4 ± 3.1 degrees in Stages 2, 3a, and 3b, respectively. There was no significant difference in hindfoot alignment among normal, Stage 2, Stage 3a. The hindfoot alignment angle was 0.5 ± 8.1 degrees, 0.5 ± 6.8 degrees, and 9.6 ± 9.1 degrees in Stages 2, 3a, and 3b, respectively.** ***Conclusion:*** **Alignment of the tibial plafond and hindfoot was variable in early stage ankle osteoarthritis.**

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INTRODUCTION

Recent reports on ankle osteoarthritis have demonstrated that the functional impairment from ankle arthritis is at least as severe as hip osteoarthritis.[2] In varus ankle osteoarthritis, disproportionate medial transmission of the load can create an adduction moment such that force across the medial part of the joint would be increased. Reports[3,9,11] on ankle osteoarthritis showed increasing varus change of tibial plafond as the stage of osteoarthritis deteriorates in varus ankle osteoarthritis. Therefore realignment by correction of tibial plafond alignment has been suggested to delay or avoid progression of osteoarthritis.[5,8–11]

Hindfoot alignment is also important for assessment of the lower extremity weightbearing axis; however, only a few articles[3,4] about ankle arthritis have measured hindfoot alignment. Hayashi et al.[3] wrote that the subtalar joint moves into valgus as a compensation to the varus change of the ankle in earlier stage varus ankle osteoarthritis but it can decompensate and change into varus at a later stage. However, we have found too great a degree of heel valgus in some ankles to regard it as compensation for ankle varus.

We have seen only a few ankles with significant deviation of alignment in early-stage osteoarthritis, in which realignment was necessary to modify the course of the disease. The purpose of this study was to investigate the alignment in ankles with early stage osteoarthritis. The hypothesis was that the alignment of the tibial plafond was variable and valgus heel alignment was common in varus ankle osteoarthritis.

MATERIALS AND METHODS

The radiographs of medial ankle osteoarthritis which were treated surgically at our hospital from 2001 to 2009 were reviewed. The diagnosis of medial ankle osteoarthritis was made from medial joint space narrowing on AP radiographs.

Patients with lateral ankle osteoarthritis, osteochondral lesions of the talus, and secondary osteoarthritis subsequent to fracture, osteonecrosis, neuropathic arthropathy, septic arthritis, rheumatoid arthritis, and other inflammatory arthropathy were excluded. Consequently, 154 ankles of 98 patients were included in this study. Fifty-one were women and 47 were men; mean age was 58.2 (range, 43 to 78) years. Eighty ankles from 80 patients (57 men and 23 women) were selected as the control group, who had no history of ankle fracture, generalized arthritis, or radiographic abnormalities. They were patients with unilateral chronic ankle pain after an ankle sprain and weightbearing radiographs of the uninvolved side were used. The mean age of these subjects was 23.4 (range, 18 to 25) years.

The radiographic assessments were made retrospectively with weightbearing ankle AP, lateral, and hindfoot alignment radiographs. All radiographs were digitally obtained through the Picture Archiving Communication System (Marosis Enterprise PACS, Infinitt, Seoul, Korea). Radiographs were taken at a tube-film distance of 100 cm with the X-ray beam projecting parallel to the tibiotalar joint.

The ankles with medial osteoarthritis were graded according to the modified Takakura classification: Stage 1, no narrowing of the joint space, but early sclerosis and formation of osteophytes; Stage 2, narrowing of the medial joint space; Stage 3, obliteration of medial space with subchondral bone contact (Stage 3a, limited to the medial malleolus; Stage 3b, extended to the roof of the dome of the talus); and Stage 4, obliteration of the whole joint space with complete bone contact. We investigated only ankles with joint space narrowing, i.e., Stage 2 and above.

On weightbearing AP radiographs, the tibial anterior surface angle (TAS), tibial axis-medial malleolus angle (TMM), and talar tilt angle were measured (Figure 1A). On weightbearing lateral radiographs, tibial lateral surface angle (TLS) was measured (Figure 1B). TLS is an angle between the tibial axis and distal tibia articular surface which is drawn between the anterior and posterior margins of the tibial plafond. On the hindfoot alignment view,[7] hindfoot alignment angle and hindfoot alignment ratio were obtained. Hindfoot alignment needs to be assessed with the angulation and translation because there are ankles with minimal angulation and large translation and ankles with large angulation with minimal translation. In ankles with minimal angulation and large translation, the heel alignment angle does not reflect the actual deviation of weightbearing axis. The heel alignment angle, which is an angle between the tibial axis and calcaneal axis, was measured and expressed as a positive number when it was in varus. Heel alignment ratio was obtained by dividing the width of the calcaneus medial to the tibial axis by calcaneal width at its widest portion on the alignment view (Figure 1C).[4]

All of the radiographs were reviewed by two authors (W.C.L. and J.S.M.) who are orthopaedic surgeons. Inter- and intraobserver reliabilities were obtained for all radiographic parameters. For the interobserver reliability, each observer measured the 40 radiographs randomly and no questions or discussions between observers were allowed during the radiographic measurement and classification. Before the start of the analysis, ten sample radiographs were evaluated together to ensure that two observers drew angles in the same manner. For the intraobserver reliability, the same radiographs were measured and classified by each observer after a month. Radiographic parameters were compared among normal and different stages of osteoarthritis. This study was approved by the institutional review board at our hospital.

Inter- and intraobserver reliability was determined by calculating weighted kappas for Takakura scales and intraclass correlation coefficients (ICCs) for continuous data. We determined the proportion of agreement of the two observers using the Cohen's Kappa statistical analysis,[1]

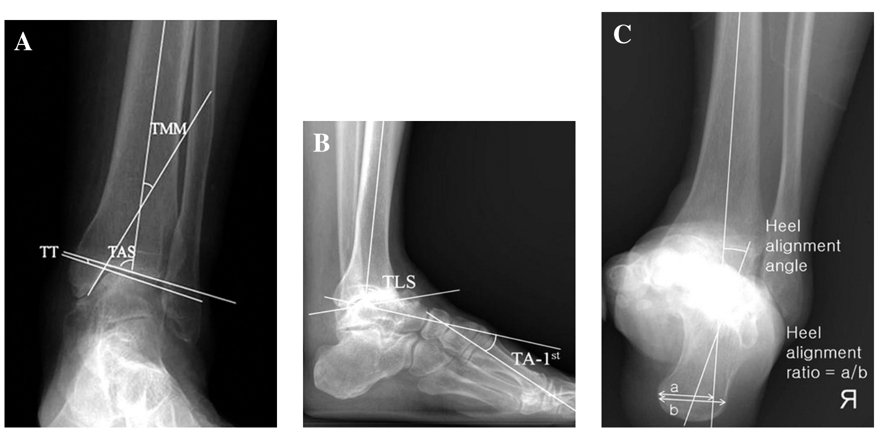

Fig. 1: Weightbearing radiographs of the ankle show radiographic parameters used to analyze medial ankle osteoarthritis. **A**, In an AP view, ankle malalignment was analyzed with the tibial-ankle surface angle (TAS), the tibial axis-medial malleolus angles (TMM), and the tibiotalar tilt angle (TT). **B**, In the lateral view, the tibial lateral surface angle (TLS), and the talo-first metatarsal angle (TA-1st) were measured. **C**, In the hindfoot alignment view, alignment angle was measured.

where kappa (k) is a coefficient of agreement corrected for chance. k can vary from 0 (complete disagreement) to 1 (complete agreement). We have used weighted kappa (kw) instead of k. Intra-class correlation coefficients were calculated by using Pearson's correlation coefficients. One-way analysis of variance (ANOVA) was used to analyze the differences between normal and each stage of Takakura classification with a Tukey post hoc test to assess difference between groups. The differences were considered statistically significant if the p value was less than 0.05. All statistical analyses were performed using SPSS version 17.0 software (SPSS Inc, Chicago, IL).

RESULTS

The reliability statistics for inter- and intraobserver comparisons are shown in Table 1. Inter- and intraobserver reliability were very high with regard to radiographic parameters except TLS.

Although there were tendencies of decrease in mean values of TAS and TLS, and increase in TMM, and talar tilt angle as the stage of osteoarthritis progressed from control group to Stage 3b, the absolute degree of difference was minimal and wide overlap was demonstrated in the graph showing the values of different Stages (Figure 2). There was no statistically significant difference in TAS among Stages 2, 3a, and 3b. Absolute value of difference of mean angles between the control group and each stage were 2.0, 2.7, and 3.5 degrees in Stage 2, 3a, and 3b, respectively. There was a significant difference of talar tilt between the control group and other groups, and between Stages 2, 3a, and 3b. The absolute value of difference of mean angles between normal and each stage were 2.5, 3.6, and 10.3 degrees, respectively. Hindfoot alignment was not statistically different among the control group, Stage 2, and 3a. It changed to heel varus of 9.6 degrees in Stage 3b, then the degree of heel varus decreased in Stage 4. Alignment ratio was 0.44, 0.46, 0.73, and 0.58, respectively for Stages 2, 3a, 3b, and 4. There was statistically significant correlation between the degree of TAS and hindfoot alignment angle or hindfoot alignment ratio; however, many ankles with a varus tibial plafond were associated with valgus heel (Figure 3 and Table 2).

DISCUSSION

The tibial plafond is known to have increasing varus as the stage of osteoarthritis deteriorates in varus ankle osteoarthritis. Hindfoot alignment can change into valgus as a compensation to the varus change of the ankle in earlier stage ankle osteoarthritis and it may tilt into varus at a later stage.[3] However, we have seen only a few ankles with significant deviation of alignment in early-stage osteoarthritis, in which realignment would be necessary to modify the course of the disease. Therefore we have investigated radiographic parameters in varus ankle osteoarthritis and our hypothesis was that there were diverse radiographic features of the tibial plafond and hindfoot in varus ankle osteoarthritis.

Among several classifications for medial osteoarthritis, the classification by Takakura et al.[11] was used in this study, since they carried out distal tibial osteotomy according to the stages of this classification. In this study, we have demonstrated its intra- and interobserver reliabilities were high.

In this study, we found that there was a trend toward decreasing values of the TAS and TLS angles, and increasing TMM angle, and talar tilt angle as the stage of osteoarthritis progressed from the control group to Stage 3b, however the absolute degree of differences were minimal and wide overlap was demonstrated in the degrees of TAS among

Table 1: Inter- and Intraobserver Reliabilities of Radiographic Findings for the 40 Randomly Selected Subjects

	Interobserver reliability		**Intraobserver reliability**	
	ICC (95%CI)	***k*w**	**ICC (95%CI)**	***k*w**
TAS(°)	0.88 (0.78–0.93)		0.86 (0.75–0.92)	
TMM(°)	0.84 (0.71–0.91)		0.88 (0.78–0.93)	
TT(°)	0.94 (0.89–0.97)		0.91 (0.83–0.95)	
TLS(°)	0.65 (0.43–0.80)		0.64 (0.42–0.79)	
Heel alignment angle	0.85 (0.73–0.92)		0.87 (0.77–0.93)	
Heel alignment ratio	0.93 (0.86–0.97)		0.96 (0.92–0.98)	
Takakura grades		0.82		0.84

ICC, Intra-class correlation coefficients; kw, weighted kappa; TAS, tibial-anterior surface angle; TMM, tibial axis-medial malleolus angles; TT, talar tilt angle; TLS, tibial lateral surface angle.

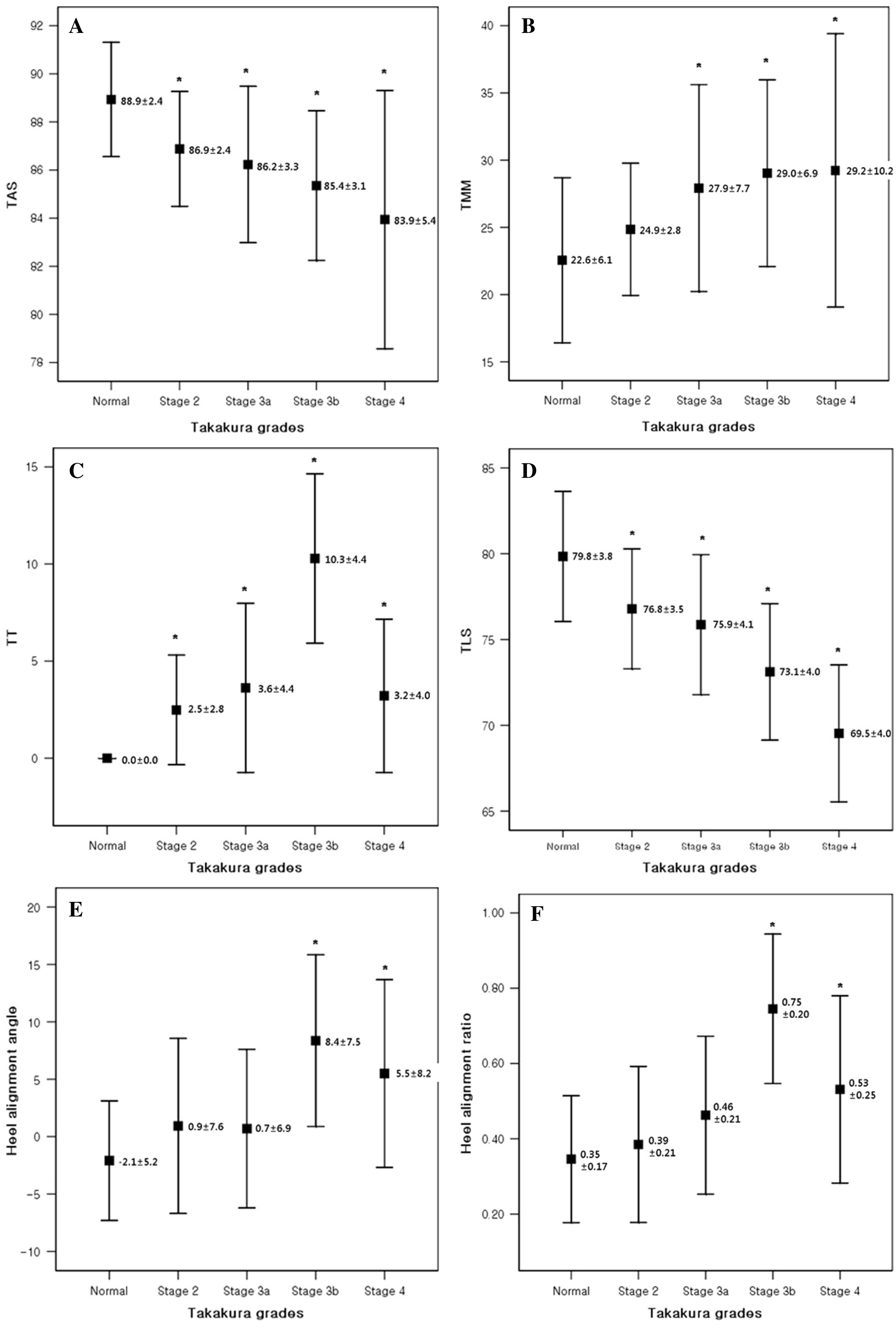

Fig. 2: The mean values (squares) and standard deviations (solid lines) of radiographic measurements for the comparison between osteoarthritis group and normal group: the tibial-ankle surface angle (TAS) (A), the tibial axis-medial malleolus angles (TMM) (B), the tibiotalar tilt angle (TT) (C), the tibial lateral surface angle (TLS) (D), the heel alignment angle (E), and the heel alignment ratio (F). *, significantly different from the normal group ($p < 0.05$).

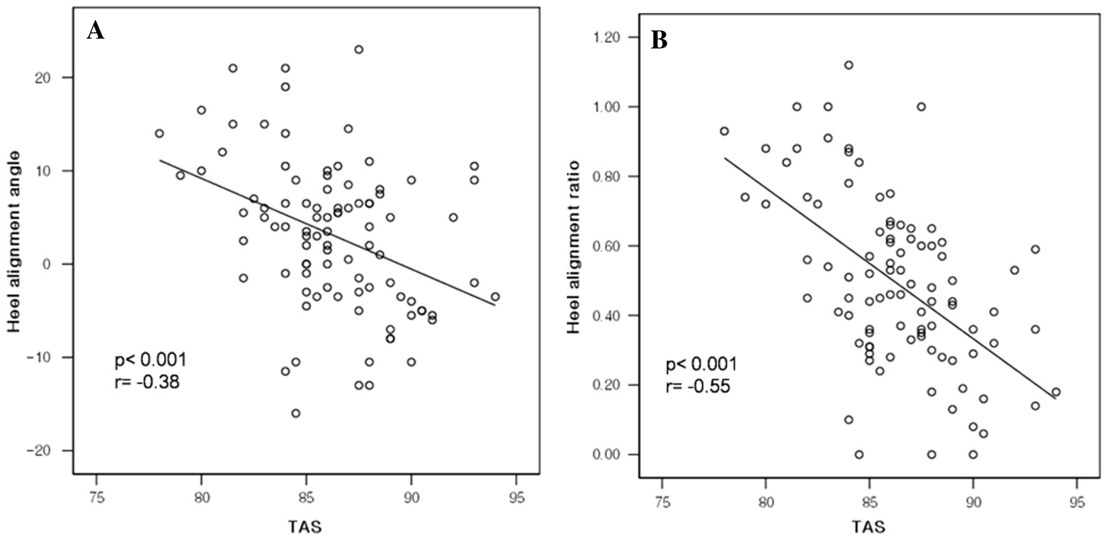

Fig. 3: Scatter plot of tibial-ankle surface angle (TAS) versus heel alignment in medial osteoarthritis. **A**, Heel alignment angle is significantly associated with TAS ($p < 0.001$, $r = -0.38$). **B**, Heel alignment ratio is also significantly associated with TAS ($p < 0.001$, $r = -0.55$).

Table 2: Comparison of Radiographic Parameters With the Takakura Classification for Medial Ankle Osteoarthritis

	Normal (n = 80)	Stage 2 (n = 68)	Stage 3a (n = 24)	Stage 3b (n = 26)	Stage 4 (n = 37)	$p^{\dagger}$
TAS(°)	88.9 ± 2.4[a]	86.9 ± 2.4[b]	86.2 ± 3.3[b]	85.4 ± 3.1[b,c]	83.9 ± 5.4[c]	0.000
TMM(°)	22.6 ± 6.1[a]	24.9 ± 2.8[a,b]	27.9 ± 7.7[b]	29.0 ± 6.9[b]	29.2 ± 10.2[b]	0.000
TT(°)	0 ± 0.0[a]	2.5 ± 2.8[b]	3.6 ± 4.4[b]	10.3 ± 4.4[c]	3.2 ± 4.0[b]	0.000
TLS(°)	79.8 ± 3.8[a]	76.8 ± 3.5[b]	75.9 ± 4.1[b]	73.1 ± 4.0[c]	69.5 ± 4.0[d]	0.000
Alignment(°)	−0.5 ± 5.4[a]	0.5 ± 8.1[a,b]	0.5 ± 6.8[a,b]	9.6 ± 9.1[c]	5.3 ± 7.9[b,c]	0.000

TAS, tibial-anterior surface angle; TMM, tibial axis-medial malleolus angles; TT, talar tilt angle; TLS, tibial lateral surface angle. Values are expressed as mean ± standard deviation. †, ANOVA test is followed by Tukey post hoc test in which each homogeneous group is labeled as ‘a,’ ‘b,’ or ‘c’ in the superscript of each value. The different letters indicate different groups which have significant difference between groups. However, if a value has superscript of ‘a’ and ‘b,’ it means that the group belongs to both Group ‘a’ and Group ‘b.’

different stages. If we consider that there is some degree of error in measurement of TAS, we believe there is only a small portion of ankles with varus osteoarthritis which have obviously deviated alignment. The absolute amount of mean difference from normal in Stage 2, 3a, and 3b was 2.0, 2.7, and 3.5 degrees, respectively. These values were slightly less than those reported previously,[3] which was 2.9, 4.0, and 5.3 degrees in Takakura Stage 2, 3a, and 3b, respectively. One assumption about the minimal varus of the tibial plafond is that the bony erosion might occur in a location other than the medial cortex of the tibial plafond. In varus ankle osteoarthritis, there were differences in talar tilt, TLS, and hindfoot alignment between Stages 2, 3a, and 3b.

Talar tilt angle was greater in Stage 3b than the other stages. Progression of joint space narrowing resulted in decrease of talar tilt in Stage 4. TMM had a tendency to increase as the osteoarthritis progressed, and we believe that resulted from erosion of the medial malleolus.

With regard to the sagittal alignment, we found the inter- and intraobserver reliability of the measurements were lower than the coronal plane parameters due to a fuzzy margin from a bony spur on the anterior margin of the distal tibia and from interposition of the tibial plafond and talus from varus tilting of the talus. The present study demonstrated that TLS decreased as the osteoarthritis deteriorated.

Different methods[3,6,7] exist to determine hindfoot alignment in radiographic views and the authors found high reliability of their measurement methods; however, all of their subjects were healthy people in those studies. Saltzmann and el-Khoury[7] measured the distance between the most distal part of the calcaneus and the longitudinal axis of the tibia. However, we had difficulty in defining the most distal part because the calcaneal outline was flat in some ankles. Another approach is to draw a calcaneal axis by connecting two points defined specifically.[6] However, we could not define specific points in the calcaneus, because it has an irregular shape and varus or valgus alignment changed the radiographic shape on the hindfoot alignment view. In this study, the calcaneal axis on the heel alignment view was drawn by visual estimation. Hayashi et al.[3] used the articular surface of the posterior facet of the calcaneus as a parameter to determine the hindfoot alignment on the hindfoot alignment view; however, they suspected their measurement reflected the alignment of the calcaneal axis. Because the posterior subtalar joint has a curved articular surface, we think the posterior articular surface of the calcaneus on the hindfoot alignment view might show a different area of the posterior facet in different individuals because of individual anatomical variance.

Heel alignment was valgus in many ankles in Stage 2, 3a, and the mean value was definitely varus in Stage 3b and Stage 4 in both heel alignment angle and heel alignment ratio. Although there may be a minimal degree of compensatory valgus in heel alignment,[2] our results demonstrated that heel alignment did not change significantly into valgus in Stage 2 and 3a, and there were a wide variety of heel alignment in the same stage of osteoarthritis. Hindfoot alignment was more than 5 degrees of valgus in 25 (16.2%) of 154 ankles and hindfoot alignment ratio was less than 0.33 in 35 ankles (22.8%). The degree of heel alignment was similar among normal, Stage 2, and 3a and it changed into varus as the degree of talar tilt increased in Stage 3b and the amount of varus angulation compensated the amount of talar tilt. Although varus change at the subtalar joint might have caused marked varus talar tilt in Stage 3b as suggested previously, we could not confirm this assumption because marked talar tilt might have caused varus heel alignment rather than the converse. Because subtalar motion was not correlated to the hindfoot alignment, we cannot exclude the possibility that patients with excellent or limited subtalar ROM have different hindfoot alignment as a compensation to the varus tilt of the talus.

The clinically important information about hindfoot alignment from this study is that there are varus tilted ankles with valgus heel alignment. Therefore the treatment for a varus tilted ankle should be carefully designed with consideration of possible lateral impingement from valgus realignment in ankles with heel valgus.

One limitation of this study is that we do not have multiple sequential radiographs so we cannot determine whether the radiographic stages of Takakura classification system represents sequential changes due to deterioration from osteoarthritis. The authors consider Takakura Stages 2 or 3a, 3b, and 4, as a sequential progression of osteoarthritis, because all parameters showed the significant change. However, it is not clear if the Stage 3a is a worse stage than Stage 2, because radiographic parameters were similar in those stages. Since the talar tilt causes asymmetric loading of the talar dome, the Stage 2 with talar tilt may directly progress to Stage 3b without the stage of 3a. A second limitation is that we have used patients with ankle pain as control subjects. Although we have used radiographs of contralateral painless ankles as control we cannot exclude the possibility that more ankles with varus alignment are included in the control group than ankles without any symptoms at all. The third limitation of this study is that overall lower extremity alignment was not investigated, and the effect of proximal malalignment on the ankle cannot be known. The fourth limitation of this study is that the relationship between the varus ankle osteoarthritis and lateral ankle instability was not investigated, because this study investigated only radiographic parameters.

This study showed that many ankles in early stage osteoarthritis do not have significant deviation of the tibial plafond and some have a substantial degree of heel valgus. Therefore, only a small portion of early ankle osteoarthritis patients would be candidates for realignment surgery, and heel alignment should be assessed together with ankle alignment.

EDITOR'S NOTE

The authors are to be congratulated for an interesting radiographic study on the tibial plafond and heel alignment in early varus osteoarthritis of the ankle. One reviewer appropriately pointed out that the contribution of ankle laxity to the progression of ankle arthritis was not assessed in this radiographic study so care should be taken when extrapolating these findings into clinical treatment or definitive conclusions regarding the etiology of the progression of varus ankle osteoarthritis.

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