Rheumatology : Current Research
ISSN: 2161-1149

Hirao et al., Rheumatol Curr Res 2013, S17
DOI: 10.4172/2161-1149.S17-002

Research Article
Open Access

Hind-mid-forefoot Deformity in Hallux Valgus Deformity in Rheumatoid Arthritis: Radiographic Evaluation Grouped by Existence of Dorsal Dislocation of Second Metatarsophalangeal Joint

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Abstract

Hallux valgus deformity combined with dorsal dislocation of the second metatarsophalangeal joint is frequently observed in rheumatoid arthritis cases. However, hallux valgus deformity without lesser toe dislocation is also seen in rheumatoid cases. Dislocated second toe cause the loss of the lateral support on the hallux, suggesting the importance to confirm the state of lesser toe MTP joint when assessing the risk of HV recurrence after surgery, and there may be some differences in the mechanical transmission between hind-mid and forefoot based on whether dorsal dislocation of the MTP joint in the lesser toe is present, although findings are unclear. This study examined the relationship between radiographic findings from the hind, mid, and forefoot and hallux valgus angle in rheumatoid arthritis cases grouped based on the presence or absence of dorsal dislocation of the second metatarsophalangeal joint. X-rays of 160 feet and ankles with rheumatoid arthritis were evaluated for the first metatarsophalangeal Larsen grade, existence of second metatarsophalangeal dorsal dislocation, hallux valgus angle, intermetatarsal angle between the first and second intermetatarsals, shape of the first metatarsal head, position of the sesamoid, the metatarsus primus varus angle, diastasis between the base of the first and second metatarsals, angle between long axis of the talus and short axis of the navicular, internal arch angle, tibio-calcaneal angle, and calcaneal lateral offset. Based on Pearson product-moment correlation coefficient test, involvement of hindfoot deformity should always be considered when assessing hallux valgus deformity in rheumatoid arthritis patients. Although mechanism of mechanical transmission through hindfoot to Lisfranc joint seems to be different by the presence or absence of dorsal dislocation of the second metatarsophalangeal joint, Lisfranc looseness also must be considered when assessing hallux valgus including the surgery to avoid the progression or recurrence in rheumatoid arthritis cases. Dorsal dislocation of the second metatarsophalangeal joint strongly influences the exacerbation of hallux valgus in rheumatoid arthritis cases. Thus, it is may be important to achieve adequate reduction of the second metatarsophalangeal joint dislocation and make a stable metatarsophalangeal joint to avoid recurrence of hallux valgus after forefoot surgery in rheumatoid arthritis.

Keywords: Dorsal dislocation of the second metatarsophalangeal joint; Hallux valgus; Valgus hindfoot; Calcaneal lateral offset; Lisfranc instability; Larsen grade; Rheumatoid arthrirtis

Introduction

In Rheumatoid Arthritis (RA), the inflammatory process within the joint synovium leads to joint erosion, ligament laxity, and subsequent destructive deformity. The rheumatoid foot is commonly affected at an early stage of RA with a prevalence of up to 90% for the forefoot. The joint of the midfoot is involved in 40 to 60% of rheumatoid patients, and the ankle and subtalar joints are involved in 30 to 60% of patients [1]. We often see forefoot deformity in RA cases along with both mid and hindfoot deformities. Generally, radiographic changes in the midfoot relate to hallux valgus (HV) progression. Enlargement of the intermetatarsal 1 and 2 (M12) angle and intermetatarsal 1 and 5 (M15) angle, metatarsus primus varus (MPV) angle, and pronated deformity of the first metatarsal joint are known to associate with HV. [2-4]. In addition, limited Lisfranc complex mobility [2] and medial column sagittal instability [5] are known risk factors for rapid progression of HV. On the other hand, some changes in the hindfoot also appear to be related to HV progression. Valgus hind foot causes abnormal and excess forefoot pressure on the medial side [6]. Furthermore, increased frequency of flat foot is correlated with first ray deformity (chiefly, MPV) [7]. In addition, pes planovalgus deformity is related to HV deformity. There is excessive influence of the abductor and adductor halluces in the pronated foot. Their line of pull direction alters as the sesamoids rotation, resulting in valgus moment [8-10], and medial arch collapse is associated with first metatarsal pronation [11]. Thus, any individual with flat foot and HV is at a greater risk of more rapid progression of HV as compared with individual with HV only, because of the forces that encourage further deformity [12]. From these observations, it is important to always consider the involvement of midfoot and hindfoot deformity when treating a forefoot deformity, including HV, in RA patients, because a forefoot deformity is often combined with a mid and hindfoot deformity in these patients. This study evaluates the relationship between the severity of HV change and radiographic changes of the fore, mid, and hindfoot in 160 feet with 80 RA patients. As is characteristic of RA forefoot deformity, HV deformity combined with dorsal dislocation of the lesser toe Metatarsophalangeal (MTP) joint is frequently observed. On the other hand, HV deformity without lesser toe dislocation is also seen. A previous report describes that dislocated second toe caused the loss of the lateral support on the hallux [13]. Then, it is important to confirm the state of lesser toe MTP

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Received February 19, 2013; **Accepted** April 19, 2013; **Published** April 22, 2013

Citation: Hirao M, Tsuboi H, Akita S, Koga T, Matsushita M (2013) Hind-mid-forefoot Deformity in Hallux Valgus Deformity in Rheumatoid Arthritis: Radiographic Evaluation Grouped by Existence of Dorsal Dislocation of Second Metatarsophalangeal Joint. Rheumatol Curr Res S17: 002. doi:10.4172/2161-1149.S17-002

joint when assessing the risk of HV recurrence after surgery, and there may be some differences in the mechanical transmission between hind-mid and forefoot based on whether dorsal dislocation of the MTP joint in the lesser toe is present, although findings are unclear. In this study, evaluations were performed after grouping RA patients based on the existence of a second MTP joint dislocation. After that, difference of the correlation between hind, mid, and forefoot parameters and hallux valgus was confirmed.

Materials and Methods

Subjects included outpatients with RA who visited our hospital from 2011. From April to September, 160 feet of 80 RA patients (male: 4, female: 72, mean age was 65.6 years old (37-85), mean disease duration was 19.8 years (2-49)) who had X-ray pictures taken of the foot and ankle while in the standing position (weightbearing dorsoplantar and lateral view of the foot, weight bearing subtalar joint radiography performed using the modified Cobey method) were evaluated. All patients had not complained against the pain in foot and /or ankle. Patients who underwent any foot and ankle surgeries before this study were excluded.

Forefoot

As shown in figure 1, the Larsen grade of the first MTP joint [14] was checked. The shape of first metatarsal head was also checked to evaluate pronation of the first metatarsal bone [4]. Linear shape was defined as grade 0, and round shape was defined as grade 1. These definitions are different from the original method [4], however it is difficult to evaluate severely destructive cases in RA, then the definition was modified and simplified (Linear shape means non-pronation of first metatarsal, while round shape means pronation of first metatarsal) in this study. The grade of the dislocation of the second MTP joint was defined as grade 0 (group D0) if no subluxation (normal or joint space narrowing without lateral shift of proximal phalanx: dorsoplantar view of the foot X-ray picture), or defined as grade 1 (group preD2) if translation of the MTP joint (lateral shift of proximal phalanx and/or overlapping of the base of proximal phalanx and the metatarsal head: dorsoplantar view of the foot X-ray picture) was noted, and as grade 2 (group D2) if complete dorsal dislocation (base of proximal phalanx completely overcomes the metatarsal head: dorsoplantar view of the foot X-ray picture) was noted. The Hardy and Clapham classification [2] was used to evaluate the sesamoid position. Measurement of HV angle was based on the recommended method [15].

Midfoot

As shown in figure 1, M12 angle and the MPV angle were measured. Definition of the first metatarsal axis is important, and measurement was based on the recommended method [15]. Diastasis between the base of the first metatarsal and second metatarsal (D12: mm) was measured to evaluate Lisfranc ligament looseness [16]. Basically, D12 is used to evaluate traumatic Lisfranc ligament injury, however expansion of D12 is often observed clinically in RA foot in the long term of inflammation and degeneration. Then in this study, D12 was measured to evaluate the looseness of Lisfranc ligament in transverse direction. The angle between the short axis of the navicular bone and the long axis of the talus bone was also measured (pronated foot index) [17]. There is another some recommended measurements for confirming pronated foot index, such as talonavicular coverage angle (TN) and talus-first metarsal angle (Talo-1MT) [18], however Talo-1MT angle is theoretically influenced by MPV angle, then we chose the measurement recommended in [17].

Hindfoot

Internal arch (IA) angle, Tibio-Calcaneal (TC) angle, and calcaneal lateral offset were measured and evaluated. The calcaneal lateral offset was defined as the distance (mm) between the axis of the tibia and calcaneus [19], as shown in figure 2.

Statistical Analysis

Willcoxon Rank Sum test and analysis of variance were used for quantitative data. All other correlates were examined using the Pearson product-moment correlation coefficient test. A p value of <0.05 was considered statistically significant.

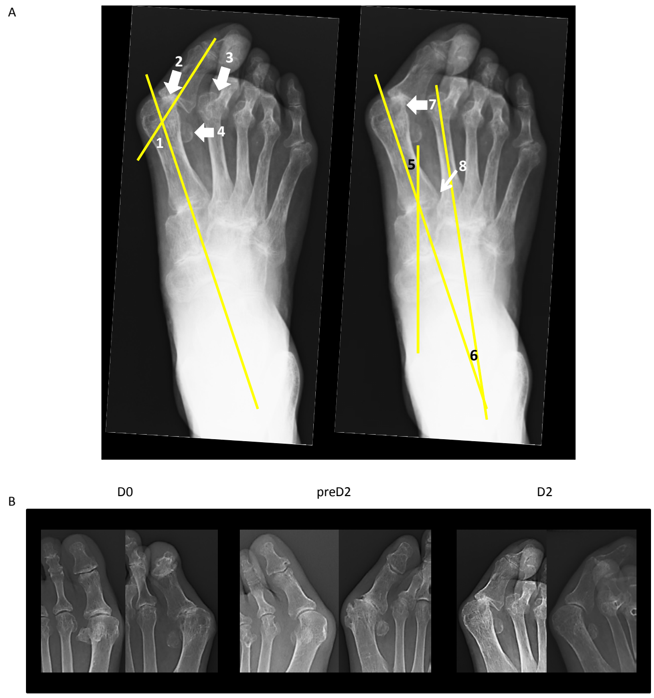

Figure 1: Radiological evaluation items in the fore and midfoot. A. 1: HV angle. 2: Larsen grade of the first MTP joint. 3: Dorsal dislocation of the second MTP joint. 4: Sesamoid position. 5: MPV angle. 6: Intermetatarsal angle between the first metatarsal and second metatarsal (M12 angle). 7: Shape of the first metatarsal head. 8: Diastasis between the base of the first metatarsal and second metatarsal (D12). B. Actual radiological examples showing second MTP joint for the classification into D0, preD2, and D2 group.

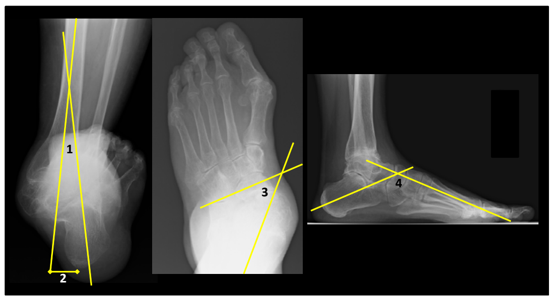

Figure 2: Radiological evaluation items in the hindfoot. 1: TC angle. 2: Calcaneal lateral offset was defined as the distance (mm) between the axis of the tibia and calcaneus. 3: The angle between short axis of the navicular bone and long axis of the talus bone (pronated foot index). 4: IA angle.

Results

Of the 160 feet, 82 feet were classified in D0 group; 59 feet were in D2 group. Remaining 19 feet were classified in preD2 group. The descriptive statistics, such as mean and standard deviation of each measurement were analyzed in these three groups. To simplify and clarify the evaluation, preD2 group was excluded from the analysis of correlation between measurement parameters. The descriptive statistics, such as mean and standard deviation of each measurement, and correlation data between measured parameters are shown in table 1 and figure 3.

MPV, M12 angle, sesamoid dislocation grade, and subsequent HV angle are gradually increased as the grade of 2nd MTP joint dislocation are getting worse

As shown in table 1, MPV angle showed 15.7 ± 6.3° in D0 group, while dislocation of 2nd MTP joint significantly increased the MPV angle (18.4 ± 6.2°). M12 angle showed 11.4 ± 5.6° in D0 group, while subluxation or dislocation significantly increased the MPV angle (preD2: 13.6 ± 4.6°, D2: 13.7 ± 4.4°). Consequently, grade of sesamoid dislocation was significantly increased from grade 3.7 ± 1.6° in D0 group to grade 4.6 ± 1.7° in preD2, and grade 5.0 ± 1.4° in D2 group. Furthermore, HV angle was also significantly increased from 20.3 ± 13.9° in D0 group to 35.5 ± 14.8° in preD2, and 44.9 ± 16.9° in D2 group.

Hindfoot deformity is associated with forefoot HV deformities and disorders in RA cases

The TC angle and calcaneal lateral offset were correlated in both the D0 group and the D2 group (D0: r=0.898, p<0.0001, D2: r=0.625, p=0.006). Furthermore, the IA angle and pronated foot index were correlated with the calcaneal lateral offset (D0: r=0.439, p=0.011 and r=-0.807, p<0.0001, respectively; D2: r=0.528, p=0.024 and r=-0.626, p=0.005, respectively). The calcaneal lateral offset and M12 angle were also correlated in both groups (D0: r=0.538 p=0.001, D2: r=0.536, p=0.022). However, the IA angle and pronated foot index were correlated with the M12 angle in the D0 group (r=0.476, p<0.0001 and r=-0.406, p=0.0004), but not in the D2 group. The calcaneal lateral offset was correlated with the MPV angle and D12 in the D2 group (r=0.506, p=0.032 and r=0.521, p=0.027), but not in the D0 group. Consequently, the IA angle and pronated foot index were correlated with the HV angle in the D0 group (r=0.464, p<0.0001 and r=-0.386, p=0.0008), whereas the pronated foot index was correlated with the HV angle in the D2 group (r=-0.406, p=0.003).

Midfoot changes associate with HV deformity in RA cases, and the effect is stronger when the second MTP joint is not dislocated. In contrast, diastasis between the base of first metatarsal and second metatarsal always weakly associate with HV deformity

In the midfoot, MPV and M12 angle were correlated with D12 in both groups (D0: r=0.500, p<0.0001 and r=0.379, p=0.0004, respectively; D2: r=0.559, p<0.0001 and r=0.474, p=0.0002, respectively). The D12 value was weakly correlated with the HV angle in both groups (D0: r=0.338, p=0.002, D2: r=0.338, p=0.01). On the other hand, the M12 angle was also correlated with the HV angle, however the correlation was strong in the D0 group (r=0.837, p<0.0001), while that was considerable in the D2 group (r=0.577, p<0.0001). The MPV angle was correlated with the HV angle in the D0 group (r=0.575, p<0.0001), but not in the D2 group. The pronation of the first metatarsal bone correlated considerably with the HV angle in the D0 group (r=0.665, p<0.0001), but was only weakly correlated with the HV angle in the D2 group (r=0.371, p=0.005).

Destructive first MTP joint and dorsal dislocation of the second MTP joint strongly associate with HV deformity in RA

In terms of forefoot findings, the grade of the sesamoid dislocation was strongly correlated with the HV angle in both groups (D0: r=0.842, D2: r=0.784). Furthermore, the mean HV angle in the D0 group was 20.3 ± 13.9°, whereas that in the D2 group was 44.9 ± 16.8° (p<0.0001), as shown in figure 3. The Larsen grade of the first MTP joint was not correlated with the HV angle in the D0 group, but was considerably correlated with the HV angle in the D2 group (r=0.541, p<0.0001).

Discussion

In this study, it was revealed that MPV angle, M12 angle, the grade of sesamoid dislocation, and subsequent HV angle were gradually increased as the grade of second MTP joint dislocation were getting worse. Although the cases in which the TC angle is large (8.6 ± 4.4°) have gathered in preD2 group, it is proper to understand that loss of lateral support by second MTP joint causes the expansion between first and second metatarsals, subsequently HV deformity exacerbates.

Next, we reconfirmed the existence of interference of hindfoot deformity to midfoot and forefoot HV deformity, in RA cases. Based on Pearson product-moment correlation coefficient test, involvement of HV deformity must be always considered when assessing forefoot deformities and disorders in RA patients whether or not there will be dorsal dislocation of second MTP joint. Indeed, we experienced a case in which HV deformity was instantly normalized by correction of severe valgus hindfoot, calcaneal lateral offset, and pronated foot deformity without any forefoot treatment [19]. Thus, careful hindfoot status evaluation is important when assessing forefoot deformity. In the D0 and D2 groups, the TC angle and calcaneal lateral offset were correlated. Furthermore, the IA angle and pronated foot index were correlated with the calcaneal lateral offset, suggesting that valgus hindfoot, flat foot, and pronated foot deformities are closely related. Interestingly, the calcaneal lateral offset and M12 angle were also in correlated in both groups; however, the IA angle and pronated foot index were correlated with the M12 angle only in the D0 group. On the other hand, the calcaneal lateral offset was correlated with the MPV angle and D12 only in the D2 group, indicating the possible difference of mechanical transmission from valgus hindfoot to midfoot of first ray based on whether there is dislocation of the second MTP joint. Consequently, IA angle and pronated foot index were correlated with the HV angle in the D0 group, while the pronated foot index was correlated with the HV angle in the D2 group. In either case, these findings indicate that valgus hindfoot and increasing of M12 and the HV angle are closely related in the RA foot.

In the midfoot, the MPV and M12 angle were correlated with D12 in both groups, suggesting that Lisfranc ligament disorder or looseness is an important factor in the expansion of the M12 angle. D12 value was weakly correlated with the HV angle in both groups, indicating that Lisfranc ligament disorder has some influence on HV exacerbation in the RA foot. Furthermore, the M12 angle was also correlated with the HV angle, as well as in idiopathic HV deformity [2,3]. However, the correlation was strong in D0 group, while that was considerable in the D2 group, indicating the different influence of the M12 angle on HV exacerbation in RA cases based on whether there is dislocation of the second MTP joint. In addition, the MPV angle was correlated

A

	Dorsal dislocation of 2nd MTP joint		
	D0	preD2	D2
TC angle (°)	3.8±7.8	8.6 ±4.4 (p=0.03)	2.0 ±6.0 (p=0.22)
Calcaneal lateral offset (mm)	9.5±13.1	14.7±9.5 (p=0.21)	7.0±9.1 (p=0.43)
IA angle (°)	143.0±9.9	148.4±11.2 (p=0.09)	140.4±8.6 (p=0.23)
Pronated foot index (°)	79.5±11.8	78.1±9.4 (p=0.38)	81.2±10.3 (p=0.29)
D12 (mm)	2.4±1.4	2.8±1.7 (p=0.32)	2.7±1.8 (p=0.16)
MPV angle (°)	15.7±6.3	18.0±6.6 (p=0.15)	18.4±6.2 (p=0.02)
M12 angle (°)	11.4±5.6	13.6±4.6 (p=0.04)	13.7±4.4 (p=0.001)
1st metatarsal pronation (grade 0-1)	0.4±0.5	0.7±0.6 (p=0.08)	0.6±0.5 (p=0.05)
Sesamiod dislocation (grade 1-7)	3.7±1.6	4.6±1.7 (p=0.03)	5.0±1.4 (p<0.0001)
Larsen grade (grade 0-5)	1.5±1.4	2.2±1.6 (p=0.07)	3.2±1.0 (p<0.0001)
HV angle (°)	20.3±13.9	35.5±14.8 (p=0.0003)	44.9±16.9 (p<0.0001)

B

		Dorsal dislocation of 2nd MTP joint	
		No	Yes
hindfoot	TC angle - Calcaneal lateral offset	r=0.898 p<0.0001	r=0.625 p=0.006
	Calcaneal lateral offset - IA angle	r=0.439 p=0.011	r=0.528 p=0.024
	Calcaneal lateral offset - pronated foot index	r=-0.807 p<0.0001	r=-0.626 p=0.005
	Calcaneal lateral offset - MPV angle	r=-0.069 p=0.7	r=0.506 p=0.032
	Calcaneal lateral offset - D12	r=-0.073 p=0.69	r=0.521 p=0.027
	Calcaneal lateral offset - M12 angle	r=0.538 p=0.001	r=0.536 p=0.022
midfoot	IA angle - pronated foot index	r=-0.566 p<0.0001	r=0.626 p=0.005
	IA angle - M12 angle	r=0.476 p<0.0001	r=0.160 p=0.238
	Pronated foot index - M12 angle	r=-0.406 p=0.0004	r=-0.199 p=0.157
	IA angle - 1st metatarsal pronation	r=0.511 p<0.0001	r=-0.079 p=0.563
	IA angle - sesamoid dislocation	r=0.539 p<0.0001	r=0.065 p=0.633
	Pronated foot index - 1st metatarsal pronation	r=-0.408 p=0.0004	r=-0.095 p=0.502
	Pronated foot index - sesamoid dislocation	r=-0.380 p=0.001	r=-0.277 p=0.047
	M12 angle - 1st metatarsal pronation	r=0.579 p<0.0001	r=0.423 p=0.001
	1st metatarsal pronation – sesamoid dislocation	r=0.656 p<0.0001	r=0.460 p=0.0003
	MPV angle - D12	r=0.500 p<0.0001	r=0.559 p<0.0001
	M12 angle - D12	r=0.379 p=0.0004	r=0.474 p=0.0002
	IA angle - HV angle	r=0.464 p<0.0001	r=0.105 p=0.443
	Pronated foot index - HV angle	r=-0.386 p=0.0008	r=-0.406 p=0.003
	M12 angle - HV angle	r=0.837 p<0.0001	r=0.577 p<0.0001
	MPV- HV angle	r=0.575 p<0.0001	r=0.193 p=0.150
	D12- HV angle	r=0.338 p<0.002	r=0.338 p=0.01
forefoot	1st metatarsal pronation – HV angle	r=0.665 p<0.0001	r=0.371 p=0.005
	Sesamoid dislocation – HV angle	r=0.843 p<0.0001	r=0.784 p<0.0001
	Larsen grade of 1st MTP joint - HV angle	r=0.171 p>0.05	r=0.541 p<0.0001

Figure 3: A: The descriptive statistics, such as mean and standard deviation of each measurement. Difference between the groups were assessed by a Willcoxon Rank Sum test. Data are shown as mean ± S.D. A p value of <0.05 was considered statistically significant, and individual p values in preD2 and D2 group were shown as compared with D0 group. **B:** Correlation data between measured parameters. Correlates were performed using the Pearson product-moment correlation coefficient test. A p value of <0.05 was considered statistically significant.

with the HV angle in the D0 group but not in the D2 group. Similarly, pronation of the first metatarsal bone correlated considerably with the HV angle in the D0 group, but was only weakly correlated in the D2 group. Taken together, it can be said that midfoot changes affect HV deformity in RA cases, and that the effect is stronger when the second MTP joint is not dislocated. Furthermore, looseness of Lisfranc joint/ligament should always be considered when assessing HV deformity in RA cases, regardless of whether second MTP joint dislocation is present. In our experience of poorly controlled RA cases, D12 was enlarged (7 mm) after hallux valgus surgery, followed by M12 angle expansion and recurrence of hallux valgus. In this case, D12 was 1.5 mm before surgery, and there was no difference of D12 comparing non-weight bearing positions and standing positions (data not shown). As described previously [20], soft tissue instability is influenced by RA control and can be a risk factor for HV exacerbation. Thus, it is thought to be important to control of disease activity of RA and Lisfranc looseness must be always considered, even if forefoot surgery has been completed.

In the forefoot findings, the grade of the sesamoid dislocation was strongly correlated with the HV angle in both groups. Furthermore, the mean HV angle in the D0 group was significantly smaller than that in the D2 group. From these observations, dorsal dislocation of the second MTP joint has a strong influence on exacerbation of HV deformity in RA. Thus, achieving adequate reduction of the second MTP joint dislocation and creating a stable MTP joint should be recommended to avoid the recurrence of HV deformity after surgery for hallux valgus and lesser toe dorsal dislocation deformity in RA. This recommendation is supported by another study that concluded that correction of the second toe deformity to make a stable lateral support on the hallux may be an important factor in successful joint-preserving surgery [21]. On the other hand, Larsen grade of the first MTP joint was not correlated with HV angle in the D0 group, while there was considerable correlation in the D2 group, suggesting that destructive HV deformity with the second MTP joint dislocation is characteristic in RA forefoot deformity, and it would be ideal to get conformity of the first MTP joint during joint-preserving surgery against HV deformity in RA cases**.** From observations in this study, though there may be a difference in the mechanism of mechanical transmission through hind to midfoot, and through mid to forefoot, hindfoot deformity correlates to HV deformity whether there is dorsal dislocation of second MTP joint or not, furthermore dislocation of second MTP joint seems to exacerbate HV deformity in collaboration with destruction of first MTP joint rather than M12 angle expansion in rheumatoid foot, as indicated in the scheme showing correlations with each hind-mid-forefoot change (Figure 4). In cases such as surgery in rheumatoid forefoot, we often see HV deformity with dislocation of lesser toes, thus it is meaningful to confirm the difference of correlation between hind-mid-forefoot changes while grouping the existence of lesser toe dislocation. In the future, relationship between valgus hindfoot and looseness of Lisfranc ligament/joint also must be further confirmed.

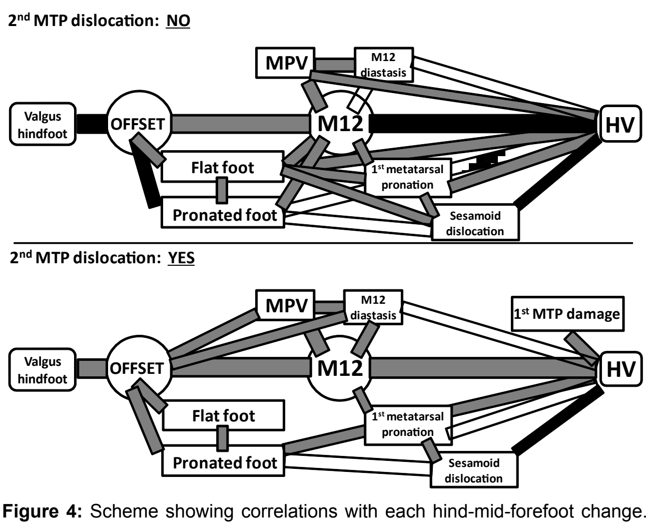

Figure 4: Scheme showing correlations with each hind-mid-forefoot change. The line smeared away black: correlation coefficient is strong (0.7-1.0). The line smeared away in gray: correlation coefficient is considerable (0.4-0.7). The line smeared away in white: correlation coefficient is weak (0.2-0.4).

Conclusion

Involvement of hindfoot deformity must be always considered when assessing HV deformity in RA patients. Although mechanism of mechanical transmission through hind to Lisfranc joint seems to be different by the presence or absence of dorsal dislocation of the second MTP joint, Lisfranc looseness also must be considered when assessing hallux valgus including the surgery to avoid the progression or recurrence in RA cases. Dorsal dislocation of the second metatarsophalangeal joint strongly influences the exacerbation of HV in RA cases. Thus, it is may be important to achieve adequate reduction of the second MTP joint dislocation and make a stable MTP joint to avoid recurrence of HV after forefoot surgery in RA.

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