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Flatfoot in the contralateral foot in patients with unilateral idiopathic clubfoot treated using the foot abduction brace

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Abstract

While the foot abduction brace (FAB) plays an important role in the Ponseti method, the true function of the FAB in the treatment of idiopathic clubfoot remains unknown. In our clinical experience, we have noted that many patients with unilateral idiopathic clubfoot developed significant flatfoot in the contralateral foot during brace treatment. The purpose of this study was to investigate the natural history of the contralateral foot development during and after brace wear. We also discuss the effect of the FAB on the contralateral foot.

We retrospectively reviewed 21 contralateral feet of 21 patients with unilateral idiopathic clubfoot who were treated using the Ponseti method and were conservatively followed up until the FAB was taken off (6 years of age or older). We evaluated flatfoot indicators of the contralateral foot on standing radiographs during and after brace wear and compared them against the normal reference ranges. We also evaluated the changes in the flatfoot indicators of the contralateral foot during and after brace wear.

Although there was a significant difference in the flatfoot indicators between the contralateral foot and normal reference ranges during brace wear, there was no significant difference in the flatfoot indicators after brace wear. While there was no significant improvement in flatfoot indicators of the contralateral foot during brace wear, there was a significant improvement or a trend to improve after brace wear. There was no significant correlation between the contralateral flatfoot and original joint laxity.

Significant flatfoot deformity was observed in the contralateral foot during brace wear. The contralateral flatfoot persisted during brace wear and improved to within normal reference ranges after brace wear. Our findings suggest that the FAB may influence the development of the contralateral foot, leading to the flatfoot.

Abbreviations: ANOVA = analysis of variance, FAB = foot abduction brace, PACS = picture archiving and communication system.

Keywords: clubfoot, flatfoot, foot abduction brace, foot development, Ponseti method

1. Introduction

Currently, the Ponseti method is widely used all over the world to treat idiopathic clubfoot. The Ponseti method involves a corrective phase, which consists of cast correction and tendo-Achilles tenotomy, and a maintenance phase, during which a brace is worn.[1] The brace used during the maintenance phase is the foot abduction brace (FAB), which consists of Denis Browne boots and a bar. The FAB plays an important role in treatment via the Ponseti method, and poor compliance with wearing the FAB is a well-known risk factor for recurrence of deformity.[2–4] While the FAB is used during the maintenance phase to preserve the correction achieved during the corrective phase, it has been reported that the FAB itself has a dynamic corrective effect.[5] The true function of the FAB in the treatment of idiopathic clubfoot is not yet fully understood. The FAB may affect foot development.

Treatment using the Ponseti method was introduced in our hospital's practice from 2004. In our experience since then, we have noted that many patients with unilateral idiopathic clubfoot developed significant flatfoot in the contralateral foot during brace treatment. However, limited information regarding the contralateral foot is available in literature. Joint laxity is known to affect the development of flatfoot during infancy.[6] The significant flatfoot in the contralateral foot of patients with unilateral idiopathic clubfoot may be related to the degree of joint laxity.

In order to address these clinical questions, we designed a retrospective and radiographic study involving data regarding the contralateral foot in patients with unilateral idiopathic clubfoot treated with the Ponseti method. The purpose of this study was to investigate the natural history of the contralateral foot development during and after brace wear. We also discuss the effect of the FAB on the contralateral foot.

2. Methods

Ethical approval for this study was provided by the institutional review board of Nagoya City University, Nagoya. The need for

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YS, KW, IW, YT, MH, and TO have contributed equally to this work.

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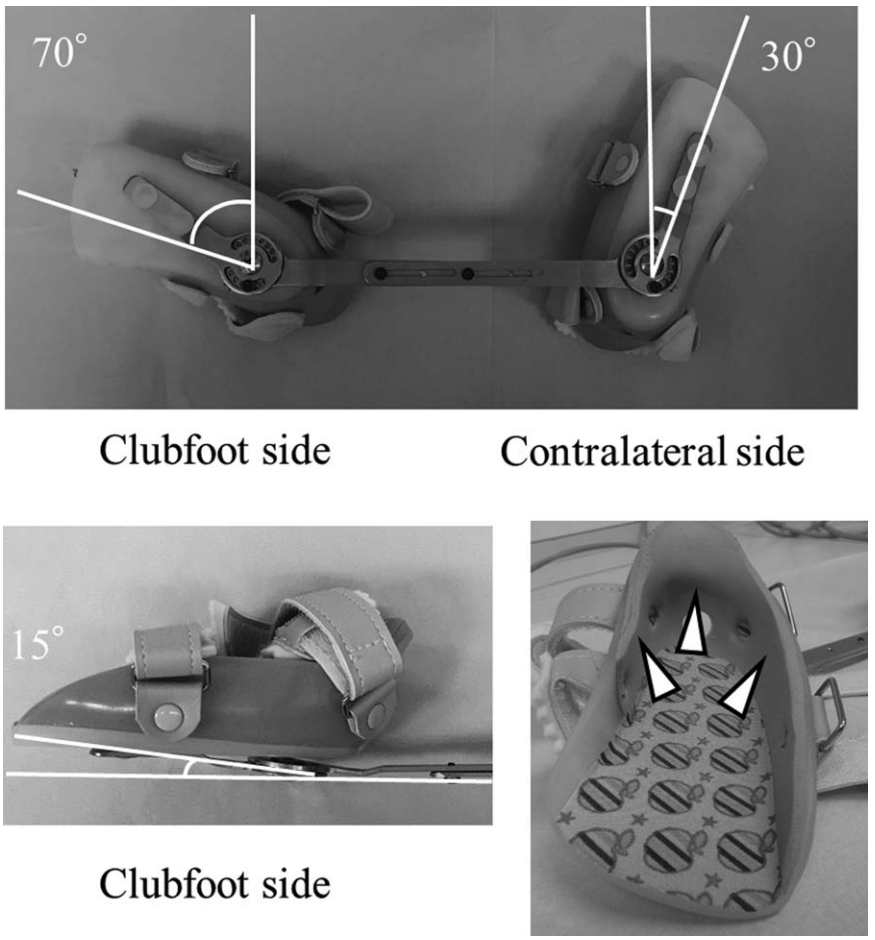

Figure 1. Foot abduction brace used in our hospital to treat idiopathic clubfoot using the Ponseti method. Molded thermoplastic ethylene-vinyl acetate (arrow head) is attached to both shoe inserts to prevent the hindfoot from sliding off.

signing the informed consent was waived because of the retrospective nature of our study and the fact that no patient identification data were included in the analysis.

2.1. Inclusion and exclusion criteria

Our study included patients with unilateral idiopathic clubfoot treated with the foot abduction brace in our hospital between 2004 and 2010. Only those patients who were able to have their first standing radiograph by the age of 3 years and were followed-up at least until the age of 6 years were included in the analysis.

The following exclusion criteria were applied in this study: neurological disorder in the contralateral foot; any disease causing joint hypermobility, such as Down's syndrome; underlying disease causing joint stiffness, such as vertical talus or arthrogryposis; and incomplete radiographic data.

2.2. Description of the brace

The brace used in our hospital is shown in Fig. 1. The shoe inserts, with the affected side set at 70° of external rotation and the contralateral side set at 30° of external rotation, are attached to the Denis Browne bar. The affected side has a shoe insert attached to provide additional dorsiflexion of 15°. The insert wraps around the heel rather than being shaped like a shoe, and molded thermoplastic ethylene-vinyl acetate is attached to the heel section to prevent the hindfoot from sliding off. Patients started wearing the FAB after the final cast correction or the tendo-Achilles tenotomy. In order to maintain the corrected position of the foot for as long as possible, our patients wore the FAB all day until they started walking while holding onto something. Subsequently, the patients wore the FAB only while sleeping, and until the age of 5 years. At every visit, we checked length of the bar and adjusted it so that the heels of the shoes were at shoulder width.

2.3. Collection of radiographic data regarding the contralateral foot in patients with unilateral clubfoot

We followed a straightforward protocol for collecting radiographic data regarding the contralateral foot in patients with unilateral clubfoot treated using the Ponseti method. After a number of cast corrections, the patient was indicated for tendo-Achilles tenotomy if the ankle dorsiflexion angle was 15° or less. As the subcutaneous tissue on the sole of the foot is thick in children, we evaluated whether true dorsiflexion was achieved based on a lateral radiograph with the foot in maximum dorsiflexion, taken with the patient's knee in flexed position. For comparison, a lateral radiograph of the contralateral foot with the foot in maximum dorsiflexion was also employed, in order to verify the extent of the original ankle dorsiflexion. After the patients started to walk and become amenable, anteroposterior and lateral standing radiographs were obtained to assess recurrence of the clubfoot. At the same time, a standing

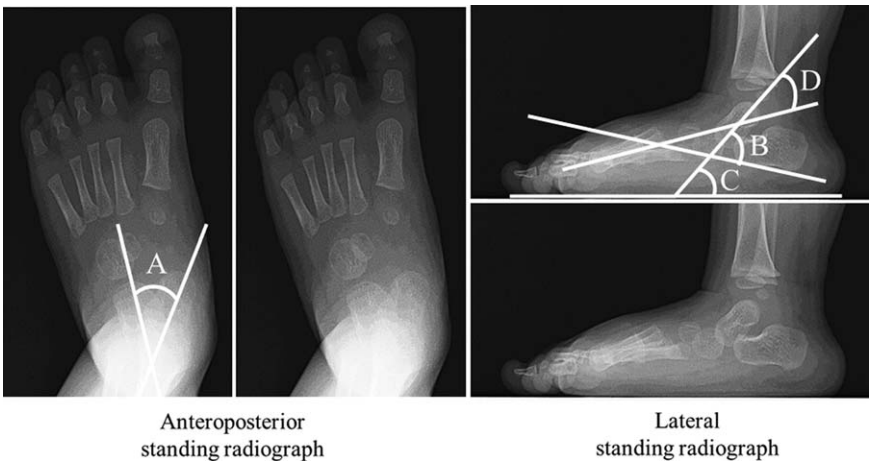

Figure 2. Flatfoot indicators on standing radiograph: anteroposterior talo-calcaneal angle (A), lateral talo-calcaneal angle (B), talus-sole-of-foot angle (C), and talo-first metatarsal angle (D).

radiograph of the contralateral foot was also obtained, to verify the original shape of the foot. Thereafter, standing radiographs of both feet were taken once a year.

The flatfoot indicators were measured on standing radiographs of the contralateral foot, as described in the study by Wenger et al.[7] These indicators were the talo-calcaneal angle on the anteroposterior radiograph, as well as the talo-calcaneal angle, talus-sole-of-foot angle, and talo-first metatarsal angle on the lateral radiograph (Fig. 2). The values of these indicators were compared with the values published by Vanderwilde et al,[8] which are considered normal reference ranges. Additionally, we analyzed the changes in the flatfoot indicators of the contralateral foot during and after brace wear. For assessing the joint laxity of the contralateral foot, we measured the tibiocalcaneal angle on the lateral radiograph (with the foot in maximum dorsiflexion) obtained before the patient started wearing the FAB. We investigated the correlation between the tibiocalcaneal angle and the flatfoot indicators on the first standing radiograph. Angle measurements on radiographs were performed using the Picture Archiving and Communication System (PACS; PSP Corporation, Tokyo, Japan).

2.4. Statistical analysis

We used the one-sample *t* test to compare the radiographic flatfoot indicators of the contralateral foot and the normal radiographic values for age-matched children. We used Pearson correlation coefficient to assess the correlation between the flatfoot indicators and the tibiocalcaneal angle. We used repeated measure analysis of variance (ANOVA) to evaluate changes in flatfoot indicators. Statistical analyses were carried out using SPSS version 23 (SPSS Inc., Chicago, IL). Statistical significance was set at $P < .05$.

3. Results

There were 25 patients who satisfied our inclusion criteria. After excluding 4 cases based on our exclusion criteria, the data for a

Table 1

Radiographic flatfoot indicators on standing radiograph in contralateral feet of patients with unilateral clubfoot and in age-matched controls with nomal values of foot parameters.

	Contralateral foot in unilateral clubfoot (N = 21)	Age-matched normal values‡	P
First standing radiograph			
Lateral talus-sole-of-foot angle, degrees†	42.0 ± 11.3 (16.5–62.0)	34 ± 8	.004*
Lateral talo-first metatarsal angle, degrees†	28.4 ± 14.0 (7.0–66.0)	13 ± 7.5	<.001*
Lateral talo-calcaneal angle, degrees†	52.3 ± 7.8 (37.7–72.4)	46 ± 5	.001*
Anteroposterior talo-calcaneal angle, degrees†	44.6 ± 7.0 (35.0–61.2)	39 ± 5	.007*
Radiograph at 2 years after the first standing radiograph			
Lateral talus-sole-of-foot angle, degrees†	43.4 ± 7.9 (29.7–57.6)	31 ± 2.5	<.001*
Lateral talo-first metatarsal angle, degrees†	20.5 ± 8.8 (1.3–36.3)	11 ± 3.0	<.001*
Lateral talo-calcaneal angle, degrees†	50.5 ± 7.6 (36.0–68.4)	46 ± 8	.024*
Anteroposterior talo-calcaneal angle, degrees†	44.3 ± 6.8 (32.6–59.2)	36 ± 3	<.001*
Radiograph at final follow-up			
Lateral talus-sole-of-foot angle, degrees†	37.1 ± 6.6 (25.5–48.8)	30 ± 4	.192
Lateral talo-first metatarsal angle, degrees†	14.0 ± 8.4 (1.6–32.3)	8 ± 6	.061
Lateral talo-calcaneal angle, degrees†	47.0 ± 8.0 (27.0–56.6)	43 ± 7	.312
Anteroposterior talo-calcaneal angle, degrees†	31.7 ± 9.6 (17.3–56.9)	34 ± 8	.456

* Statistically significant ($P < .05$).

† Data are represented as mean ± standard deviation (range) unless otherwise specified.

‡ Data are age-matched normal values published by Vanderwilde et al.[8]

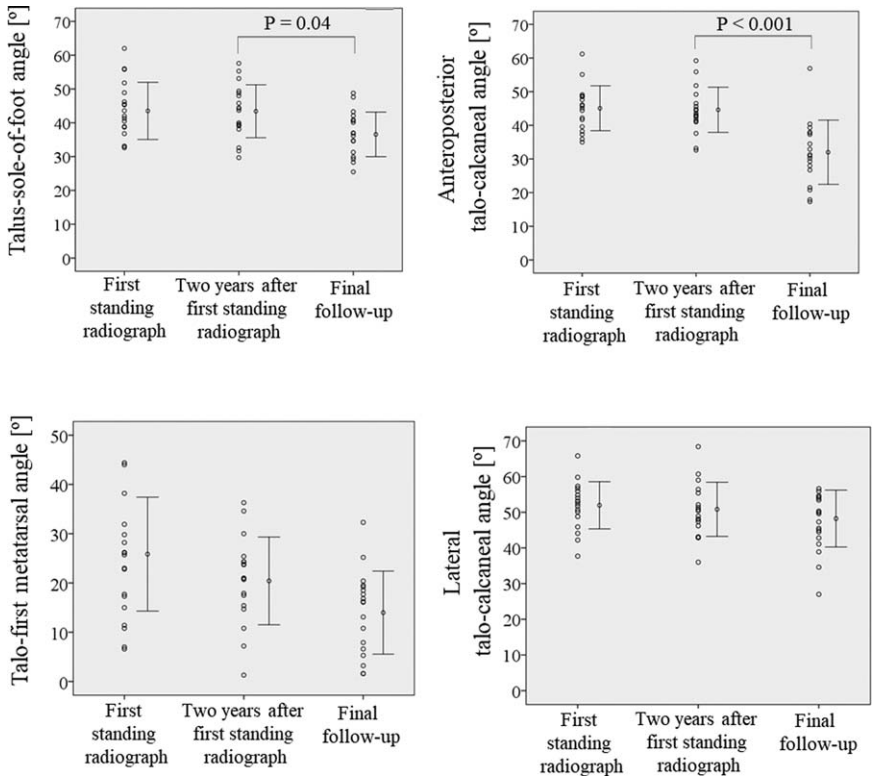

Figure 3. Changes in the flatfoot indicators of the contralateral foot in patients with unilateral clubfoot. Circles indicate average values, while error bars indicate standard deviation. Scatter plots provide all data points.

total 21 patients (21 contralateral feet) were included in our analysis. There were 18 boys and 3 girls. Clubfoot was noted on the right side in 13 feet, and on the left side in 8 feet.

The age at the beginning of FAB treatment was 75 ± 14 days (range, 55–112 days). The average age at the time of walking while holding onto something was 11.3 ± 2.4 months (range, 7.0–16.0 months). The average age at the first standing radiograph was 1.8 ± 0.7 years (range, 1.0–3.1 years). The mean age at final follow-up was 7.9 ± 1.7 years (range, 6.0–9.0 years). There were 9 cases (42%) of clubfoot recurrence, which required surgery (posterior release, n = 5; posterior-medial-lateral release, n = 4). The mean age at the time of surgery for recurrence was 3.2 ± 2.1 years (range, 1.1–6.7 years).

3.1. Flatfoot indicators of the contralateral foot

At final follow-up, no patients presented with symptoms such as pain, tendency to have fatigue, or plantar callosities in the contralateral foot.

The flatfoot indicators of the contralateral foot are shown in Table 1. On first standing radiograph and at 2 years after the first standing radiograph, the values of the flatfoot indicators of the contralateral foot were significantly larger than the age-matched normal values. On the standing radiograph at final follow-up, there was no significant difference between the values of the flatfoot indicators of the contralateral foot and the age-matched normal values.

The changes in the flatfoot indicators of the contralateral foot are shown in Fig. 3. There was no significant improvement in flatfoot indicators during the 2 years of follow-up after the first standing radiograph (*P* values: .96, .60, .94, and .74 for the talus-sole-of-foot angle, talo-first metatarsal angle, anteroposterior talo-calcaneal angle, and lateral talo-calcaneal angle, respectively). The average talus-sole-of-foot angle and anteroposterior talo-calcaneal angle at final follow-up had decreased significantly from the values noted at 2 years after the first standing radiograph (*P* values: .04 and <.01 for the talus-sole-of-foot angle and anteroposterior talo-calcaneal angle, respectively).

Table 2

Correlation between joint laxity and flatfoot indicators on standing radiograph in contralateral feet of patients with unilateral clubfoot.

	Pearson correlation coefficient	
	Lateral tibiocalcaneal angle, degrees*	*P*
Lateral talus-sole-of-foot angle, degrees†	−0.25	.32
Lateral talo-first metatarsal angle, degrees†	0.08	.74
Lateral talo-calcaneal angle, degrees†	−0.23	.37
Anteroposterior talo-calcaneal angle, degrees†	0.05	.85

* Measurements were taken on lateral radiograph before applying the foot abduction brace, with the foot in maximum dorsiflexion.
† Measurements were taken on first standing radiograph.

Although talo-first metatarsal angles and lateral talo-calcaneal angles tended to be smaller at final follow-up than at 2 years after the first standing radiograph, this difference did not reach statistical significance (*P* values: .12 and .18 for talo-first metatarsal angle and lateral talo-calcaneal angle, respectively).

3.2. Relationship between joint laxity and flatfoot indicators of the contralateral foot in patients with unilateral clubfoot

The average tibiocalcaneal angle on lateral radiograph (with the foot in maximum dorsiflexion) before wearing the FAB was 36.9° ±13.5° (8.7°–64.8°). There was no significant correlation between the tibiocalcaneal angle and the values of the flatfoot indicators (Table 2).

4. Discussion

We identified a significant degree of contralateral flatfoot on the first standing radiograph. Morley[9] reported that flatfeet are seen in 97% of children aged 2 years and younger, while Staheli et al[10] reported that flatfeet are seen in 54% of 3-year-old children. According to these researchers, many children at this age have flatfoot. Wenger and Leach[11] stated that flexible flatfoot in children is related to loose ligaments and joints in the foot, so that flatfoot is induced when weight is placed on the foot. Theoretically, pronounced joint laxity will lead to significant flatfoot. However, our results showed that there was no significant correlation between original joint laxity (before FAB treatment) and flatfoot indicators of the contralateral foot. Specifically, patients with pronounced joint laxity of the contralateral foot did not always show large values of flatfoot indicators on the first standing radiograph. These observations suggest that factors other than joint laxity may affect the development of flatfoot in the contralateral foot. One factor to be considered is that, compared with the clubfoot, the contralateral foot bears greater weight because the patients have difficulty placing full weight on the clubfoot. Among other factors, FAB may also contribute to the development of the contralateral foot in these patients.

Our results showed significant improvements in some flatfoot indicators of the contralateral foot after the FAB was taken off. On the other hand, we found no significant improvement during the time that the patients wore the brace, even though flexible flatfoot in children is generally thought to improve naturally over time.[7–8,10] Yamamoto et al[5] stated that, when 1 leg is extended and the other knee is flexed as a result of wearing the FAB with the Denis Browne bar, the foot on the flexed side is forced into dorsiflexion, abduction, and eversion. Thacker et al[12] reported that the Diméglio score[13] improves when the FAB is worn. Janicki et al[14] reported that the FAB is superior to ankle foot orthosis, as the brace with abduction of the foot is required to stretch the soft tissue on the posteromedial side of the foot. It is known that, in patients with idiopathic clubfoot, there is contracture of the soft tissue on the posteromedial side of the foot.[15] Ponseti and Becker[16] stated that the FAB is not indicated for congenital metatarsus adductus, since its use will accentuate the valgus deformity of the heel. Taken together, this information and our results suggest that the newly developed flatfoot in the contralateral foot of patients with unilateral clubfoot treated using the FAB is best explained by a dynamic corrective effect of the FAB on the development of the contralateral foot. The FAB might exert a stretching effect on the posteromedial soft tissue of the contralateral foot, with no contracture. While our present study did not include a biomechanical investigation of the FAB effect, our findings may be interpreted to suggest that the FAB increased the degree of contralateral flatfoot and then maintained flatfoot during the treatment period that involved full-time and night-time brace wear, respectively, and that removal of the corrective effect of the brace allowed for normal development of the contralateral foot. The particular shape of our FAB might have somehow influenced the contralateral foot.

The strength of this study was that we radiographically demonstrated the significant flatfoot on the contralateral side during brace wear, followed by improvement to normal reference after brace wear. Our findings have significant clinical complications. Mosca[17] stated that if there is contracture of the Achilles tendon in flexible flatfoot, this can lead to disorders, including pain during adolescence. In the present series, the contralateral flatfoot indicators improved to the age-matched normal values at final follow-up. However, if significant flatfoot on the contralateral side persists during brace wear, it may cause contracture of the Achilles tendon. Thus, it is important to be aware of the contralateral flatfoot while using the FAB, and to proceed with management of the flatfoot deformity. Ponseti[18] stated that the FAB should be removed shortly after the child starts walking when overcorrection of the clubfoot is expected. Moreover, Staheli[19] described that if excessive heel valgus is found on the clubfoot side, the adduction angle of the shoes should be reduced. Therefore, when significant flatfoot is found on the contralateral side, reducing the adduction angle of the contralateral shoe and the length of time wearing the brace may represent effective treatment options to manage contralateral flatfoot, provided that there is no recurrence of the clubfoot. Stretching the Achilles tendon on the contralateral side might also be helpful.

Our retrospective study has several limitations. First, we were unable to verify the accuracy of the information extracted from the medical records regarding the time that the FAB was worn (FAB compliance). Although we confirmed that the parents complied with FAB at every visit and emphasized the importance of the FAB, true FAB compliance remains unknown. Second, body weight may affect the development of flatfoot. We were unable to obtain data such as the patients' height and body weight at the time of each standing radiograph from the medical records. Third, the follow-up period was relatively short. Specifically, the maximum period of radiographic observation in this study was 9 years. Follow-up into adulthood will be required to evaluate the natural history of the contralateral foot development. Fourth, the number of cases was small. Considering these limitations, further study is warranted.

5. Conclusion

We found that significant flatfoot developed in the contralateral foot during brace wear. The severity of flatfoot was not related to original joint laxity in the contralateral foot. The contralateral flatfoot persisted throughout the brace treatment period (when the brace was worn full-time or at night), and improved to normal reference only after the FAB was taken off. Our findings suggest that the FAB may influence the development of the contralateral foot, leading to the flatfoot.

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