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Comparison of mid-term efficacy of spastic flatfoot in ambulant children with cerebral palsy by 2 different methods

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Abstract

To compare the treatment efficacy of spastic flatfoot surgery by 2 different surgical methods: nonfusion subtalar arthroereisis using subtalar joint stabilizer (SJS) and Dennyson–Fulford subtalar arthrodesis (D-FSA).

A total of 26 cases of ambulant children with cerebral palsy diagnosed as spastic flatfoot were surgically treated from January 2011 to December 2014. Preoperative and postoperative American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) scores, anteroposterior–talocalcaneal angles (ATAs), and lateral talar-first metatarsal angles (Meary angles) of the affected foot were recorded.

Among 12 children in the SJS group, the AOFAS-AH scores were median preoperative score of 61 (58–64) versus median postoperative score of 83 (75–92), with significant difference ($P < .05$). Of the 20 feet treated, only 1 foot developed occasional pain. Postoperative ATA was decreased from preoperative 35° (20°–50°) to 19° (12°–25°); lateral X-ray films showed that the Meary angle was decreased from preoperative 20° (15°–40°) to postoperative 0° (0°–3°). The differences in both findings were statistically significant ($P < .05$). Fourteen children (22 treated feet) formed the D-FSA group; all demonstrated fusion of the talocalcaneal joint; AOFAS-AH scores were median preoperative score of 61 (58–64) versus median postoperative score of 83 (75–92), with significant difference ($P < .05$). Only 1 foot had occasional pain. Postoperative ATA was decreased from preoperative 35° (20°–45°) to 16° (12°–25°); lateral X-ray films showed that the Meary angle was decreased from preoperative 19° (10°–40°) to postoperative 2° (0°–5°); the differences in both findings were statistically significant ($P < .05$).

Both nonfusion subtalar arthroereisis using SJS and D-FSA were effective for the surgical treatment of spastic flatfoot, with similar clinical outcomes.

Abbreviations: AFO = ankle-foot orthosis, AOFAS-AH = American Orthopedic Foot and Ankle Society-Ankle and Hindfoot, ATAs = anteroposterior–talocalcaneal angles, CP = cerebral palsy, D-FSA = Dennyson–Fulford subtalar arthrodesis, SJS = subtalar joint stabilizer.

Keywords: ambulant children with cerebral palsy, Dennyson–Fulford subtalar arthrodesis, nonfusion subtalar arthroereisis, spastic flatfoot

1. Introduction

Ambulant children with cerebral palsy (CP) often present with flatfoot and other musculoskeletal malformations mainly due to muscle spasm, muscle strength imbalance, bone anomaly, and joint capsule relaxation.[1] The pathological changes include the collapse of the medial longitudinal arch of the foot, forefoot supination, and hindfoot valgus.[2] The affected foot often progress into a rigid, painful, and severe deformity, and cause changes of the foot skin such as pressure ulcer, hallux valgus, etc. leading to serious clinical consequences.[3]

Aiona and Sussman[4] believed that the natural history of the spastic flatfoot begins with unbalanced muscles' strength besides the subtalar joints, then contracture of the muscles causes skeletal changes like heel valgus and lateral displacement of the calcaneus. Upon further progression, secondary skeletal developmental malformation occurs complicated with osteoarthritis of the talocalcaneal joint, the talonavicular joint, and the metatarsophalangeal joint, thereby completely losing the potential of spontaneous relief.[5] With time this deformity becomes more rigid and the talus head is excessively protruded inducing pain and restricting shoe wear, and painful plantar corpus callosum changes occur, restricting independent walking distance or even completely losing walking ability.[6]

Treatments of the spastic flatfoot include conservative or surgical management. Conservative treatments[4] include the use of insole, ankle-foot orthosis (AFO), and the use of assistive devices. Botulinum injection and baclofen pump therapy have also been tried. But because of the weakness of the posterior tibial tendon and of the sustained spasm of peroneus, the therapeutic effects of conservative treatment for spastic flatfoot are poor.[7,8] Ultimately, the presence of pain and fixed deformities require surgical intervention.[9–12]

We used subtalar joint stabilizer (SJS) for subtalar arthroereisis and the Dennyson–Fulford subtalar arthrodesis (D-FSA) as

surgical corrective procedures. Our study was based on the hypothesis that the spastic flatfoot can also be treated with SJS.

2. Methods

2.1. General information

Inclusion criteria: Ambulant children with grade I and grade II CP (according to the Gross Motor Function Classification System) were diagnosed with spastic flatfoot based on history, physical examination, and X-ray; foot surgery had not been previously performed; the affected foot was without bony deformities such as tarsal coalitions, vertical talus, etc.; foot pain was present and could not be relieved by conservative treatment.

Included subjects were treated from January 2011 to December 2014. Twelve patients (20 feet) were treated with SJS including 8 boys and 4 girls aged 5 to 12 years old (average 7.8 years old). Among them, 8 cases underwent bilateral surgery. The average follow-up time in the SJS group was 28.3 ± 7.9 months (20–48 months). In addition, 14 children (22 feet) were treated with D-FSA including 9 boys and 5 girls aged 6 to 15 years (average 9.2 years old). Among them, 8 cases underwent bilateral surgery. The average follow-up time in the D-FSA group was 31.9 ± 10.7 months (22–60 months).

This research was approved by the Medical ethics committee of Hunan provincial people's hospital.

2.2. Surgical approaches

General anesthesia was administered to all patients undergoing both surgeries and all the patients maintained a supine position during surgery. A lateral tarsal sinus approach was used for the children treated with the SJS. A skin incision of 1 to 2 cm was performed at the anterior–inferior tarsal sinus to the lateral malleolus and the soft tissue was bluntly dissected. The guiding needle was placed in the tarsal canal through the tarsal sinus. An appropriate size of the test mold was selected, and the appropriate size of stabilizer was placed with the foot in neutral position, assuring that the subtalar joint maintained a movement range of 30° to 40°. The precise placement of SJS was confirmed by fluoroscopy.

An oblique skin incision was performed along the normal dermatoglyphics above the anterior lateral tarsal sinus of the affected foot in patients who underwent D-FSA. The dorsal talar neck was completely exposed through the interval between the extensor longus digitorum and anterior tibial neurovascular bundle. The calcaneus was rotated under the talus, and the forefoot was maintained in the normal neutral position and plantarflexion. Under the assistance of fluoroscopy, the articulatio talonavicularis was confirmed, as well as the inserted position of the guiding needle along the direction from the talar neck to the calcaneus with about 5° in the anteroposterior position. The drill was first performed without tapping, and then hollow screws with the appropriate size (4.5 mm diameter) were screwed to maintain the position of the foot. Another incision was performed at the partes iliaca. The cancellous iliac bone was reserved. The lower surface of talus and the upper surface of the cartilage-free surface of the calcaneus were roughened by the raspatory. The cancellous iliac bone was transplanted to fill the tarsal sinus.

Muscle force adjustment surgery was additionally performed in all children. The Achilles tendon lengthening was performed in children with Achilles tendon tension in the 10 patients in the SJS

group and 13 patients in the D-FSA group. Gastrocnemius tendon lengthening was performed in the remaining children who did not undergo the Achilles tendon lengthening. Peroneus lengthening was jointly performed in the children with peroneus tension in the SJS group and the D-FSA group for 8 and 10 cases, respectively.

2.3. Postoperative management

All children were stabilized with the long leg plaster cast for 4 weeks after surgery. The plaster cast was removed and replaced by hinged AFO in the SJS group 4 weeks later. The screws were routinely left in the tarsal sinus without removal if there were no symptoms in the children.

2.4. Efficacy assessment

The patients were reviewed in the outpatient department every 3 months after discharge for a year. Then a 6-monthly outpatient visit was requested. The clinical effects of the affected foot were assessed according to the American Orthopedic Foot and Ankle Society-Ankle and Hindfoot score (AOFAS-AH) by the same physician at every review in the outpatient department. X-ray examinations were performed every 3 months to compare the changes of the anteroposterior–talocalcaneal angle (ATA) and positive lateral talar-first metatarsal angle (Meary angle).

2.5. Statistical analysis

The data were analyzed by SPSS software, and the measurement data were represented as median (Min, Max). The Wilcoxon Signed Ranks Test was used to compare the difference of preoperative and postoperative scores and imaging parameters in each group, the Mann–Whitney test was used to compare the difference of preoperative and postoperative scores and imaging parameters between 2 groups, and the α value of 0.05 in 2-tailed test was considered as significant.

3. Results

All patients were followed up to 20 to 60 months with an average follow-up time of 30.2 ± 9.5 months. No wound-related problem or vital vascular and nerve injury was found during follow-up. One patient in each group complained of local pain. Both children had undergone bilateral surgery and the pain was present in 1 foot. The pain was relieved after the internal fixation removal surgery. Such a secondary surgery was not performed in the remaining children. Screw fracture appeared in only 1 patient (1 foot in the D-FSA group) during the follow-up period (Fig. 3). However, the pain and movement disorders were absent in all other patients and the family members did not request for the removal of the internal fixation. No loosening or fracture of the internal fixation devices were found in other patients. The postoperative pain and foot arrangement were largely improved in all patients. Children in the SJS group were followed up after surgery with AOFAS-AH scores: the median preoperative score was 61 (58–64), and the median postoperative score was 83 (75–92) (Table 1). There was a significant difference between the preoperative and postoperative scores ($P < .05$), and only 1 foot (as described earlier) had occasional pain. Postoperative ATA was decreased from preoperative 35° (20°–50°) to 19° (12°–25°). Lateral X-ray films showed that Meary angle was decreased from preoperative 20° (15°–40°) to 0° (0°–3°), and the differences in

Figure 1. Boy, aged 6, Case No. 10, bilateral spastic flatfoot, Gross Motor Function Classification System grade II in the subtalar joint stabilizer group. Right foot American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) scoring was 64 points during preoperative assessment and 92 points at 30 months follow-up. The talocalcaneal angle was 30° in the preoperative assessment and 15° at 30 months follow-up. The Meary angle was 30° during the preoperative assessment and 0° at 30 months follow-up. Left foot AOFAS-AH scoring was 61 points during the preoperative assessment and 83 points at 30 months follow-up. The talocalcaneal angle was 40° during the preoperative assessment and 20° at 30 months follow-up. The Meary angle was 40° during the preoperative assessment and 0° at 30 months follow-up.

both angle findings were statistically significant ($P < .05$) (Fig. 1). All children in the D-FSA group had good fusion of the talocalcaneal joint, and the postoperative AOFAS-AH scores were as follows: median preoperative score was 61 (58–64) and median postoperative score was 83 (75–92) (Fig. 2). There was a significant difference between the preoperative and postoperative scores ($P < .05$), and only 1 foot (as described earlier) had occasional pain. Postoperative ATA was decreased from preoperative 35° (20°–45°) to postoperative 16° (12°–25°).

Lateral X-ray films showed the Meary angle was decreased from preoperative 19° (10°–40°) to postoperative 2° (0°–5°), and the differences in both findings were statistically significant ($P < .05$) (Tables 1–5).

4. Discussion

Hefti et al[13] believed that if the pain of the spastic flatfoot is ignored for a long time, it would cause functional changes of the

Table 1

Details of patients in the subtalar joint stabilizer group.

No.	Gender	Age, y	Unilateral/ bilateral	Follow-up time, mo	Left/ right	Preoperative AOFAS-AH score	Postoperative AOFAS-AH score	Preoperative talocalcaneal angle, °	Postoperative talocalcaneal angle, °	Preoperative Meary angle, °	Postoperative Meary angle, °
1	Girl	5	Unilateral	36	Right	64	87	20	15	27	2
2	Boy	9	Bilateral	48	Right	61	83	40	25	15	0
					Left	64	92	35	20	20	0
3	Girl	12	Bilateral	24	Right	58	75	40	25	15	3
					Left	61	83	45	25	16	2
4	Boy	10	Unilateral	22	Right	61	75	30	18	20	3
5	Girl	6	Bilateral	22	Right	61	87	35	20	30	0
					Left	64	83	50	20	20	0
6	Boy	8	Unilateral	34	Right	64	75	25	20	15	3
7	Boy	6	Bilateral	26	Right	64	83	30	20	30	3
					Left	61	87	35	15	25	2
8	Boy	8	Bilateral	25	Right	64	92	35	15	20	0
					Left	58	83	30	12	15	0
9	Girl	7	Unilateral	28	Right	61	83	30	15	20	2
10	Boy	6	Bilateral	30	Right	64	92	30	15	30	0
					Left	61	83	40	20	40	0
11	Boy	7	Unilateral	20	Left	61	83	35	15	16	0
12	Boy	9	Unilateral	24	Left	64	92	40	15	15	0

AOFAS-AH = American Orthopedic Foot and Ankle Society-Ankle and Hindfoot.

Figure 2. Boy, aged 6, Case No. 2, bilateral spastic flatfoot, Gross Motor Function Classification System grade I in the Dennyson–Fulford subtalar arthrodesis group. Right foot American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) scoring was 61 points during preoperative assessment and 75 points at 48 months follow-up. The talocalcaneal angle was 35° during the preoperative assessment and 15° at 48 months follow-up. The Meary angle was 15° during the preoperative assessment and 2° at 48 months follow-up. Left foot AOFAS-AH scoring was 64 points during the preoperative assessment and 75 points at 48 months follow-up. The talocalcaneal angle was 30° during the preoperative assessment and 20° at 48 months follow-up. The Meary angle was 24° during the preoperative assessment and 0° at 48 months follow-up.

foot. When the medial weight-bearing area of the foot becomes obviously higher than the lateral side, surgical treatment should be considered.[14–16]

In 1946, Chambers[17] first proposed the idea of using autogenous bone to implant into the tarsal sinus to restrict the range of subtalar joint activity. Grice[18] used extra-articular subtalar arthrodesis combined with tarsal sinus bone graft to treat flatfoot children. LeLievre[19] proposed the method of implanting temporary staple into lateral subtalar joint for retardation. Afterward, Subotnick[20] first described the method of implanting rubber prosthesis into the tarsal sinus for subtalar joint retardation. Smith and Millar[21] used polyethylene screw implant into the tarsal sinus for subtalar joint retardation, and the success rate was 96%. Zaret and Myerson[22] treated 23 cases of flatfoot children using tapered implant for subtalar joint retardation, and the incidence of postoperative tarsal sinus pain was 18%. Vedantam et al[23] reported the application of polyethylene tarsal sinus screw in 78 cases of flatfoot children,

Figure 3. Boy, aged 6, Case No. 1, bilateral spastic flatfoot, Gross Motor Function Classification System grade II. Screw fracture of the right foot was found at 18 months follow-up. Right foot American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) scoring was 58 points during the preoperative assessment and 75 points at the last (60 months) follow-up. The talocalcaneal angle was 35° during the preoperative assessment and 20° at the last follow-up. The Meary angle was 20° during the preoperative assessment and 2° at the last follow-up. Left foot AOFAS-AH scoring was 61 points during preoperative assessment and 83 points at the last follow-up. The talocalcaneal angle was 45° during the preoperative assessment and 25° at the last follow-up. The Meary angle was 24° during the preoperative assessment and 3° at the last follow-up.

Table 2

Details of patients in the Dennyson–Fulford subtalar arthrodesis group.

No.	Gender	Age, y	Unilateral/ bilateral	Follow-up time, mo	Left/ right	Preoperative score	Postoperative score	Preoperative talocalcaneal angle, °	Postoperative talocalcaneal angle, °	Preoperative Meary angle, °	Postoperative Meary angle, °
1	Boy	6	Bilateral	60	Right	58	75	35	20	20	2
					Left	61	83	45	25	24	3
2	Boy	6	Bilateral	48	Right	61	75	35	15	15	2
					Left	64	75	30	20	24	0
3	Boy	10	Unilateral	32	Left	61	75	25	16	15	5
4	Girl	7	Bilateral	36	Right	58	83	35	13	20	2
					Left	61	87	35	15	30	5
5	Girl	10	Unilateral	28	Right	58	83	40	15	18	2
6	Boy	15	Bilateral	23	Right	61	83	35	15	20	2
					Left	58	75	30	20	18	0
7	Boy	9	Unilateral	34	Right	61	83	35	20	12	0
8	Girl	11	Bilateral	26	Right	64	75	25	15	15	2
					Left	61	83	30	15	20	3
9	Boy	13	Bilateral	28	Right	64	87	35	20	10	0
					Left	61	83	40	15	12	0
10	Boy	8	Unilateral	22	Right	64	83	35	18	18	2
11	Girl	11	Unilateral	30	Right	64	87	40	12	20	2
12	Girl	10	Bilateral	24	Right	64	92	20	15	35	0
					Left	61	75	35	20	40	0
13	Boy	6	Unilateral	22	Left	64	87	35	15	20	3
14	Boy	7	Bilateral	34	Right	61	75	25	20	15	0
					Left	61	83	35	20	16	2

and the satisfaction rate was as high as 96%, and no degradation occurred in the implant. Roth et al[24] treated 48 cases of flatfoot children by using screw implantation in tarsal sinus for subtalar joint retardation with an excellent rate of 91.5% at 5 years follow-up.

Although SJS has been widely applied in flatfoot children, the application in spastic flatfoot has rarely been reported. In this study, the Meary angles on the lateral radiographs of children in the SJS group could all be recovered to within 4° during follow-up visits. The anteroposterior radiographs showed that the calcaneal valgus was significantly better than before, and could be recovered to within 30°. This demonstrated that the foot force line was well restored, and the improvement rate of postoperative pain was 95%, reflecting the surgery had a good effect in treating spastic flatfoot. The literature has reported that the most common postoperative complications of SJS surgery were tarsal sinus pain, insufficient or excessive correction caused by inappropriate size of the stabilizer, too much intrusion or protrusion of the implants, related synovitis, vascular/nerve related injury, spontaneous fusion of subtalar joint, and talus neck fracture.[25] Black et al[26] used the implants designed by Viladot to treat flatfoot children, and the incidence of postoperative pain was 73%. But 36% of the children

had to have their implants removed due to invalid correction. Afterward the implant was abandoned. Gutierrez and Lara[27] reported that postoperative supine immobilization could solve the problem of pain, but the time taken was long (1–4 months). The general treatment method was to remove the implant. Over-correction was an important cause of tarsal sinus pain, and the solution was also implant removal.[28] In this study, only 1 patient had tarsal sinus pain, while other patients had no pain. The reasons might be that the appropriate size of the stabilizer, weakening of the valgus strength after the intramuscular lengthening of the peroneus brevis muscle in most patients, long postoperative plaster fixation time, and good healing of soft tissues. The patient who developed pain received bilateral surgery and the postoperative pain occurred only in 1 foot. Pain was not significantly improved after the outpatient use of nonsteroidal anti-inflammatory drugs, and the pain finally disappeared after the removal of the internal fixation. A possible reason might be that the patient did not receive intramuscular lengthening surgery of the peroneus brevis muscle, the sustained muscle spasms and body weight were both exerted to the foot, and the valgus strength was not controlled and eventually caused pain.

Table 3

The differences between the preoperative and postoperative indexes in patients of the subtalar joint stabilizer group.

	Before surgery	After surgery	P
Score	61 (58–64)	83 (75–92)	<.001
The first metatarsal angle, °	35 (20–50)	19 (12–25)	<.001
Meary angle, °	20 (15–40)	0 (0–3)	<.001

The values of the American Orthopedic Foot and Ankle Society-Ankle and Hindfoot score, anteroposterior–talocalcaneal angle, and positive lateral talar-first metatarsal angle (Meary angle) after surgery were significantly improved compared with those before surgery, P<.05. The results suggested that the spastic flatfoot could be improved by using this approach.

Table 4

The differences between the preoperative and postoperative indexes in patients of the Dennyson–Fulford subtalar arthrodesis group.

	Before surgery	After surgery	P
Score	61 (58–64)	83 (75–92)	<.001
The first metatarsal angle, °	35 (20–45)	16 (12–25)	<.001
Meary angle, °	19 (10–40)	2 (0–5)	<.001

The values of the American Orthopedic Foot and Ankle Society-Ankle and Hindfoot score, anteroposterior–talocalcaneal angle, and positive lateral talar-first metatarsal angle (Meary angle) after surgery were significantly improved compared with that before surgery, P<.05. The result suggested that the spastic flatfoot could be improved by using this approach.

Table 5

Comparison of the improvement between the preoperative and postoperative indexes in the patients of the 2 groups.

	The improved value in the arthrodesis group	The improved value in the stabilizer group	*P*
Difference of score	22 (11–28)	22 (11–28)	.140
Difference of the first metatarsal angle, °	15 (5–28)	15 (5–30)	.978
Difference of Meary angle, °	17 (10–40)	19 (12–40)	.258

The improved degrees of the American Orthopedic Foot and Ankle Society-Ankle and Hindfoot score, anteroposterior–talocalcaneal angle, and positive lateral talar-first metatarsal angle (Meary angle) between preoperative and postoperative values were used. The differences between these 2 groups showed no significance, *P* > .05. These results indicated the similar therapeutic effect between the 2 groups of surgical methods on spastic flatfoot.

The D-FSA is one of the joint fusion surgeries, first used by Grice on the treatment of flatfoot[29] and the satisfactory rate was 78%. In 1977, Bratberg and Scheer[30] got their satisfactory rate up to 74% in 573 pediatric patients. In 1994, Hadley et al[31] reviewed 46 cases of pediatric patients, with a success rate of up to 70%, but with a false joint formation rate of about 6.4%. In 1976, Dennyson and Fulford[32] further proposed the use of a metallic internal fixation screw to reduce the incidence of false joint and the recurrence rate of the deformity. In our study, all patients achieved bony fusion at the last follow-up, and no false joint occurred. Meary angle on the lateral radiographs was found to be recovered from preoperative 20° to postoperative 1.7°, and the calcaneal valgus on the posteroanterior radiographs was found to be recovered from preoperative 33° to postoperative 17°. The foot force line was well restored, and the relief rate of postoperative pain was up to 95%. To avoid false joint formation, we suggest that the activity and flexibility of the subtalar joint should be clarified before surgery. The downward state of the talonavicular joint must be confirmed and maintained during the operation. Under the assistance of the fluoroscopy, the line between the long axis of the talus and navicular bone at the anteroposterior position should be maintained at the position of approximately 5° of the valgus. The position of the screw should be located at the dorsal side of the talus neck and in the gap between the extensor digitorum longus and the anterior tibial neurovascular bundle. The anterior tibial neurovascular bundle should be protected to avoid injury. All fat and soft tissues inside the tarsal sinus should be carefully cleaned before bone graft, and the lower surface of the talus and the nonarticular upper surface of the calcaneus should be roughened by the raspatory. The use of iliac cancellous bone graft for filling could effectively prevent the formation of false joint.

Our study results demonstrated that the SJS group as well as the D-FSA group had good therapeutic effect for the spastic flatfoot. Several aspects of AOFAS-AH scores, ATAs, and lateral Meary angles were significantly improved after operation, and the results were statistically significant. Comparison between the groups suggested that there were no significant difference in the improvement rate of the 2 methods, indicating that both the methods had their own advantages in the treatment of spastic flatfoot and close successful clinical effects. But the procedure of the SJS retained the activity of the talocalcaneal joint. If this method was invalid or caused pain, the patient could receive arthrodesis or other surgical treatment methods after the removal of the stabilizer. The patients who underwent D-FSA were treated with iliac bone graft, and due to more skin incisions compared with the SJS implantation, they had an increased risk of more complications, such as infection of the bone graft area, implant fracture, bone graft fusion failure, etc. In this study, 1 patient in D-FSA group had a screw fracture in 1 foot in the follow-up period (Fig. 3). But the child did not appear to have any symptoms of pain or disability. Thus, the internal fixation was not removed, and the patient is still being monitored for this during follow-up. In addition, we suggest that the contracture of peroneus brevis muscle of flatfoot children should be monitored before and during surgery to determine whether during the D-FSA procedure there was a need of peroneus brevis muscle lengthening in order to balance the force of the inner and outer strength of the foot. The follow-up time in our study was relatively short, and long-term status of the foot line could not be provided. We plan a further follow-up study where we would observe these indicators to get more detailed data.

5. Conclusions

In conclusion, both nonfusion subtalar arthroereisis and D-FSA had good therapeutic effects for spastic flatfoot. Three indicators of the 2 surgical methods before and after the operation were compared: there were no significant differences in the improvement degrees of the AOFAS-AH functional scores, ATAs, and Meary angles, indicating that the 2 methods had close clinical effects for spastic flatfoot.

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