The Journal of Foot & Ankle Surgery 58 (2019) 904–915

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Arthroereisis for Symptomatic Flexible Flatfoot Deformity in Young Children: Radiological Assessment and Short-Term Follow-Up

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ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:
heel
joint
pediatric
subtalar
talonavicular
tendon

ABSTRACT

The purpose of this study is to recognize those young patients with symptomatic flexible flatfoot deformity who need treatment and to provide radiological evidence that arthroereisis is capable of relocating the talus properly over the calcaneus. We included 28 feet in 14 children who underwent subtalar arthroereisis in association with percutaneous triple-hemisection Achilles tendon lengthening. Selected for arthroereisis were children with symptomatic flexible flatfoot deformity who complained of foot and leg pain, had decreased endurance in sports activities and long walks, who did not respond to conservative treatment modalities for at least 6 months, and in whom at radiological assessment on stance position with the medial arch support orthosis the talonavicular joint lateral subluxation still remained, with Meary's angle in anteroposterior (A/P) and lateral view remaining increased. The mean age at surgery was 10.71 ± 1.58 (range 8 to 14) years. The minimum follow-up duration was 19 months, with mean follow-up duration of 35.14 ± 9.82 (range 19 to 60) months. For estimation of the efficacy of the surgical procedure, the American Orthopaedic Foot and Ankle Society (AFOAS) rating scale was used preoperatively and postoperatively in all patients. The mean preoperative AFOAS ankle-hind foot rating score was 65.14 ± 7.16 (range 58 to 75) points. The mean postoperative AFOAS score was 88.851 ± 5.61 (range 83 to 97) points and the 2-tailed *p* value <.0001. After arthroereisis surgical treatment, all AOFAS scores and all foot angles improved significantly, except the calcaneal inclination angle which improved slightly.

The flexible flatfoot deformity is a static and dynamic foot deformity in which the patient is unable to support the body weight at its 3 contact areas to the ground (plantar aspect of the calcaneus, plantar aspect of the head of first and fifth metatarsal), with total collapse of the longitudinal medial arch support, driving the calcaneus in valgus position (1). On stance position, the subtalar joint is collapsed into pronation so that the sinus tarsi (a small cylindrical cavity) is squashed down. As the calcaneus comes into supination, the sinus tarsi opens; as the calcaneus comes into pronation, it closes. If the sinus tarsi is propped open, the calcaneus is propped into a more supinated position. and can, therefore, correct a pronated calcaneus. The valgus position of the heel is aggravated by the shortness of the Achilles tendon. Maintenance of the talonavicular joint subluxation and the valgus position of the heel, owing to subtalar joint eversion, progressively can cause stretching, fatigue, and lesion of the elongated tibialis posterior tendon. Moreover, rupture of the calcaneonavicular plantar (otherwise known as spring) ligament may follow, owing to its inability to compensate for the lack of active support of the tibialis posterior, thus worsening the deformity and symptoms.

Weightbearing radiographs have been deemed adequate for detecting and quantifying flatfoot; they are requested as complementary to the clinical assessment for assessing flatfoot severity and in making decisions on treatment (2). They are also used in postoperative assessment to verify alignment, even though their role and limitations in this context remain under debate (3,4).

At present, there is no definite agreement on the indications to treat flatfoot in children when painful and causing dysfunction. With regard to different treatments proposed for flatfoot deformity, primary randomized high-quality studies are lacking. The first choice usually consists of prescribing insoles, which in some cases have been reported as a way to achieve relief from pain (5,6). Other more sophisticated orthotics have also been introduced as options, but in children compliance may be a problem; thus their use is not widespread (7). Corrective shoes are also a common prescription from physicians to tackle severe hindfoot deformities (8). Recent systematic reviews have concluded that there is no evidence in favor of orthotics, bracing, and stretching exercises for children (9). Regardless of the kind of treatment, after the failure of conservative measures, surgery should be taken into consideration. Among

Financial Disclosure: None reported.
Conflict of Interest: None reported.
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https://doi.org/10.1053/j.jfas.2019.01.012

Table 1
Children with symptomatic flexible flatfoot deformity: data

ID	Gender	Age	Meary's Angle Lateral Preop	Meary's Angle A/P Preop	Kite's Angle Lateral Preop	Kite's Angle A/P Preop	Calcaneal Inclination Angle Preop	Talar Declination Angle Preop	Talonavicular Subluxation Preop	Meary's Angle Lateral Postop	Kite's Angle Lateral Postop	Kite's Angle A/P Postop	Calcaneal Inclination Angle Postop	Talar Declination Angle Postop	Talonavicular Subluxation Postop	AOFAS Score Preop	AOFAS Score Postop
1	Male	11.00	9.3°	17.6°	35.6°	45.8°	15.4°	23.3°	Mod	1.9°	33.5°	25°	17.6°	16.2°	Normal	75.00	97.00
2	Female	9.00	24.5°	43.4°	53.2°	29.6°	10.2°	36.2°	Sev	2.8°	31°	13.8°	14.9°	17.3°	Mild	58.00	83.00
3	Male	10.00	25°	44.1°	53.7°	31.1°	8.1°	36.8°	Sev	3.6°	31.6°	1.4°	14°	18.7°	Mild	58.00	83.00
4	Male	11.00	24°	43°	52.5°	30.5°	9°	35.1°	Sev	3°	30,8°	21.2°	15°	17.8°	Mild	58.00	83.00
5	Female	12.00	10.6°	19.4°	36.2°	38.6°	13.3°	25.1°	Mod	2.1°	31,6°	24°	16.7°	17.3°	Normal	72.00	93.00
6	Male	9.00	11.2°	21.1°	37.1°	41.4°	12.7°	26.3°	Mod	2.4°	30,3°	19.3°	16.1°	18.6°	Normal	72.00	93.00
7	Female	10.00	12.4°	22.2°	38.3°	39.8°	13.1°	26.9°	Mod	3.3°	30,4°	22.7°	15.7°	19.4°	Normal	72.00	93.00
8	Male	12.00	24.3°	43.3°	53°	30.3°	8.4°	36.1°	Sev	2.9°	31°	24.6°	14.8°	17.4°	Mild	58.00	83.00
9	Male	10.00	23°	42°	52°	31.4°	9.1°	35°	Sev	3°	30°	16.8°	15°	18.8°	Mild	64.00	90.00
10	Male	12.00	9.5°	17.9°	36°	42.2°	14.8°	24.1°	Mod	2.4°	33.1°	25.8°	17°	17.3°	Normal	75.00	97.00
11	Male	10.00	23°	42°	52.1°	29.9°	9.6°	35.2°	Sev	2.6°	31.1°	15.8°	14.1°	17°	Mild	64.00	90.00
12	Female	12.00	24°	43.1°	53°	33.4°	8.6°	36°	Sev	3°	32°	20.6°	14.8°	17.4°	Mild	58.00	83.00
13	Male	8.00	21°	30.9°	46°	28.4°	9°	33°	Sev	2.3°	31.6°	21.5°	15°	17°	Mild	70.00	93.00
14	Male	14.00	24°	43°	53.1°	33.8°	8°	36°	Sev	2.4°	32°	16.7°	14.5°	17.6°	Mild	58.00	83.00

Table 2
Flatfoot deformity treated with arthroereisis: follow-up duration

N	Months
Valid	14
Missing	0
Mean	35.1429
Standard Deviation	9.82036
Range	41.00
Minimum	19.00
Maximum	60.00

soft-tissue procedures, an Achilles tendon lengthening is usually indicated in cases of contracture (10,11). Subtalar arthroereisis involves inserting a barrel-shaped implant into the sinus tarsi between middle and posterior facets of the subtalar joint through a small skin incision to keep the sinus tarsi open and block excessive subtalar joint pronation, elevating the talus at the same time. Metcalfe et al (12) also analyzed extensively the available evidence regarding subtalar arthroereisis in treating flatfoot. In terms of outcome, they underlined that few studies had applied validated clinical or patient-reported outcome measures. Furthermore, they showed that, despite a wide variation in radiological parameters utilized among different studies and their unclear relationship with clinical status, radiographic measures were often adopted as markers of success after surgery. The most used was the calcaneal inclination and talar declination angles, but several other parameters have been reported to indicate the arch height increase and the improvement in the hindfoot-midfoot axis (12). Overall, Metcalfe et al concluded that arthroereisis appeared capable of correcting flatfoot, but that it was still an evolving technique based more on clinical experience than evidence-based data. Obviously, they suggested the use in further studies of validated disease-specific patient outcome tools (12). When considering arthroereisis alone, all authors reporting results on different cohorts (noncomparative studies) have concluded that this minimally invasive procedure was an "optimal" technique for the correction of flexible flatfoot in children (13,14), providing

Table 3
Flatfoot sheet questionnaire

NAME: URNAME: GE:

POSITIVE FAMILY HISTORY

BILATERAL UNILATERAL LEFT RIGHT

SYMPTOMATIC NON SYMPTOMATIC

DECREASED ENDURANCE:

PAIN

MEDIAL ARCH SINUS TARSI CALCANEUS

MEDIAL ARCH DEPRESSION
MILD MODERATE SEVERE

HEEL VALGUS POSITION

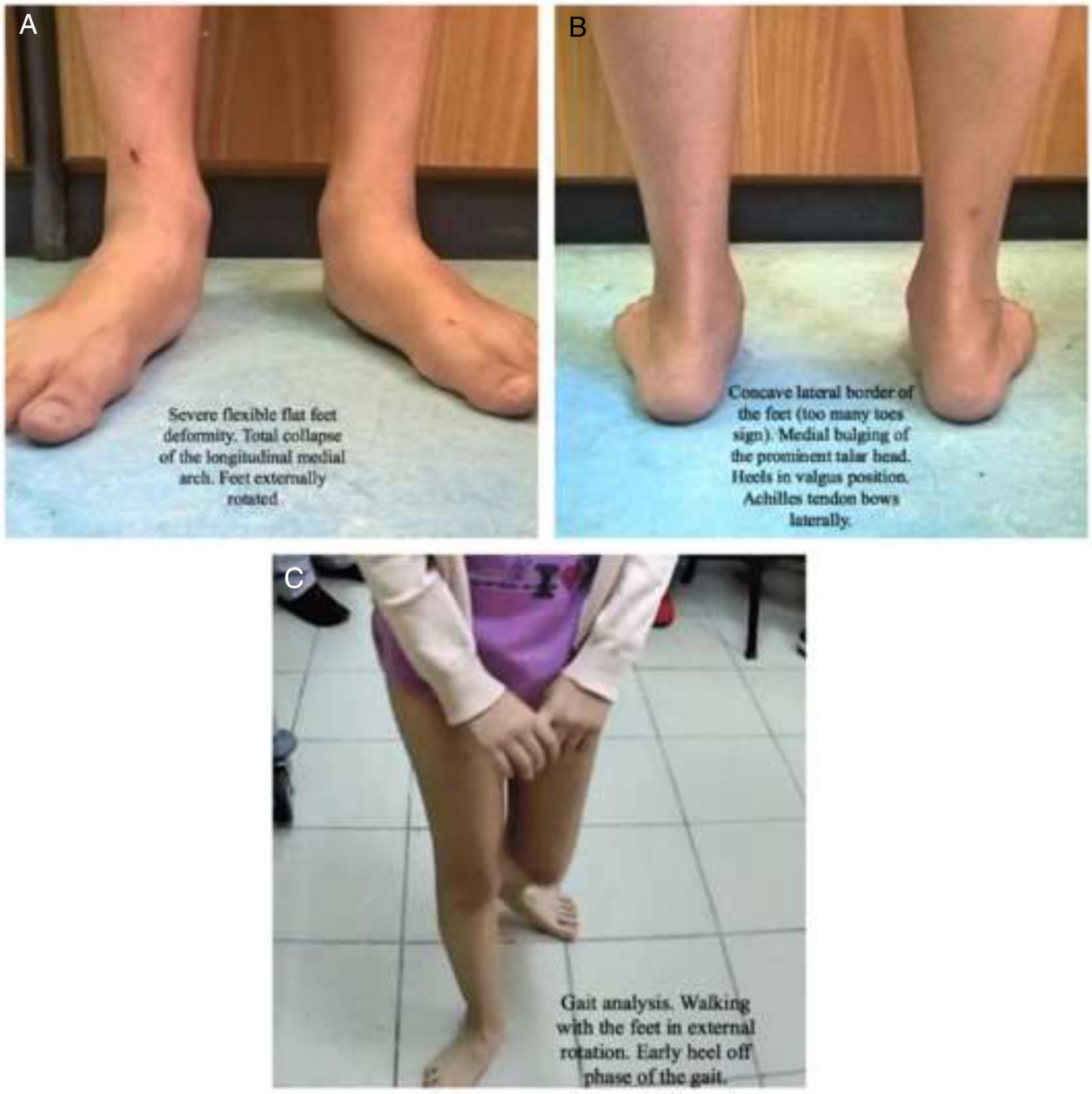

Fig. 1. (*A*) Excessive midfoot and forefoot abduction ("too many toes" sign), indicating also lateral subluxation of the talonavicular and calcaneocuboid joint. (*B*) Heels in valgus position, owing to eversion of the subtalar joint. Achilles tendon bows laterally, owing to Achilles tendon shortness, exacerbating heels valgus position. (*C*) Gait with excessive midfoot and forefoot abduction.

clinical and radiological satisfying outcomes. In conclusion, the purpose of arthroereisis in symptomatic flatfoot deformity in children is to restore back to its normal position the subtalar joint, relocating the talus properly over the calcaneus, to allow remodeling of these bones during the rest of their growing period. Complications may be divided into 4 main categories, including the consequences of inappropriate indications, technical error, adaptation/irritation, and biomaterial failure (15). Among these, the most common complication is undoubtedly sinus tarsi pain (12,16,17), regardless of the fact that most authors have reported its complete resolution after implant removal (18,19). However, in more recent studies, the overall complication rate was considered negligible at between 0% and 11% (14,20).

The 4 AOFAS scales continue to be some of the most widely used instruments in clinical studies, and they remain in use at a substantially higher rate than other scales that have been validated (21–23). Both the ankle and hindfoot measures are easy to apply and understand. Because of their wide use in the literature, AOFAS score values still offer the best comparison between different studies. This outcome measurement tool is not validated specifically for use in the pediatric population.

Patients and Methods

A total of 14 (N = 14) patients were included in the analyses. Of these, 10 (71.42%) were males and 4 (28.57%) were females. There were 28 (100%) feet with symptomatic flexible flatfoot deformity in this cohort. Between 2012 and 2015 they were treated

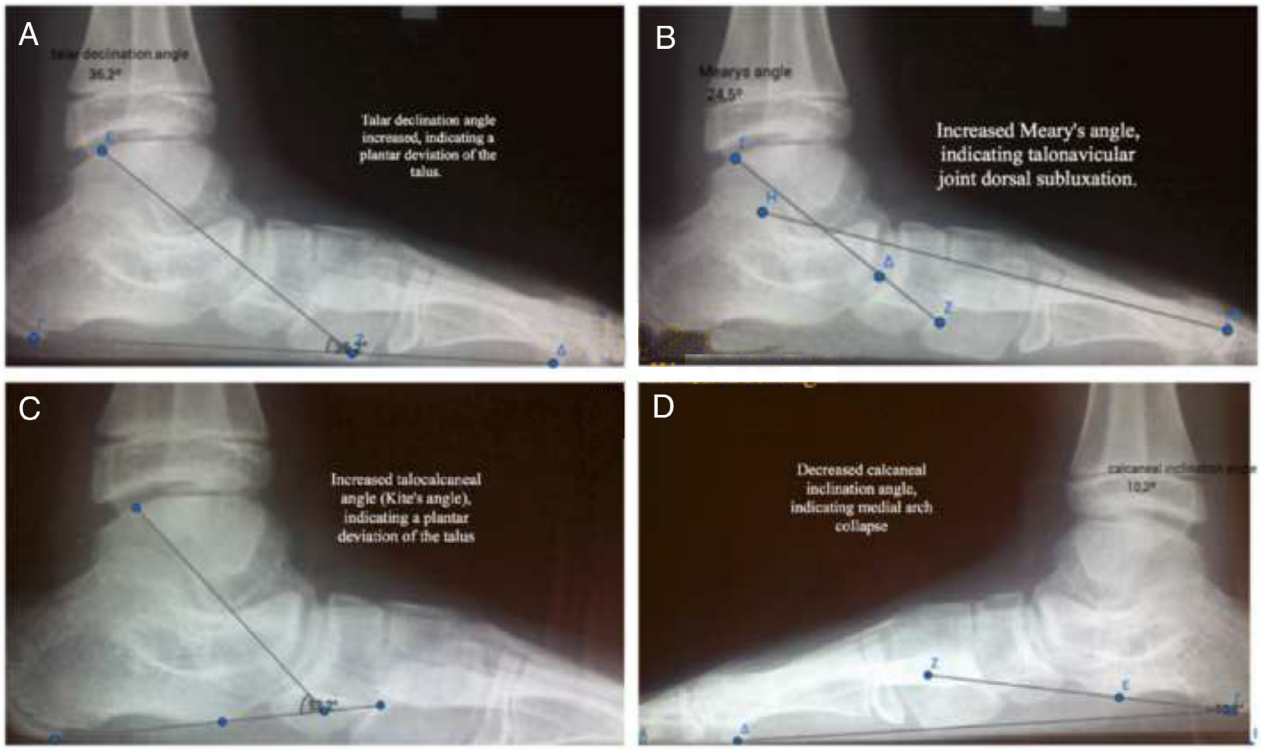

Fig. 2. (*A*) Radiograph weightbearing lateral view. Increased Meary's angle, indicating talonavicular joint dorsal subluxation, with dorsal displacement of the medial foot ray (navicular, medial cuneiform, first metatarsal, great toe). (*B*) Radiograph weightbearing lateral view. Decreased calcaneal inclination angle, indicating a longitudinal medial arch collapse. (*C*) Radiograph weightbearing lateral view. Increased talar declination angle, indicating a plantar deviation of the talus. (*D*) Radiograph weightbearing lateral view. Increased talocalcaneal angle, indicating a plantar deviation of the talus. Patient ID 2 in Table 1.

surgically by the corresponding author (M.P.), with subtalar arthroereisis, using MBA subtalar implant Integra (size 10 mm in 20 feet [71.42%], and 8 mm in the remaining 8 feet [28.57%]) in combination with triple-hemisection percutaneous Achilles tendon lengthening (Hoke technique) (24) (Table 1). Selected for arthroereisis were children with symptomatic flexible flatfoot deformity who complained of foot and leg pain, had decreased endurance in sports activities and long walks, who did not respond to conservative treatment modalities for at least 6 months, and in whom at radiological assessment on stance position with the medial arch support orthosis the talonavicular joint lateral subluxation still remained, with Meary's angle in anteroposterior (A/P) and lateral view remaining increased. Children with symptomatic feet, in whom at the radiological assessment on stance position, with the medial arch support orthosis, the talonavicular joint lateral subluxation was corrected, and the Meary's angle in A/P and lateral view were at the near edge of the lower normal limit, were advised to continue with conservative modalities, and were followed at regular 6-month intervals until skeletal maturity. The mean age at surgery was 10.71 ± 1.58 (range 8 to 14) years. The minimum follow-up duration was 19 months, with mean follow-up duration of 35.14 ± 9.82 (range 19 to 60) months (Table 2). Patients with a flatfoot deformity secondary to a neuromuscular disease and tarsal coalition were excluded.

For estimation of the severity of the flatfoot deformity in each patient, a flatfoot sheet questionnaire (Table 3) was used, which included patients complaints and the clinical and radiological assessment. All the children shared common clinical and radiological features. The estimation of the severity of the flatfeet deformity was made by author M.P. On clinical presentation of each patient, in the stance position, we noticed: total collapse of the longitudinal medial arch, feet externally rotated, plantar and medial bulging of the prominent talar head, (leaving the plantar and medial talar articular surface uncovered) concave lateral border of the feet with excessive midfoot and forefoot abduction ("too many toes" sign), heels in a valgus position, and Achilles tendon bowing laterally, owing to Achilles tendon shortness, exacerbating heel valgus position (Fig. 1). Tenderness at tibialis posterior tendon insertion was noted, indicating tendon stretching, and the possibility of development of progressive tibialis posterior tendon insufficiency in the future. Tenderness over the sinus tarsi, indicating sinus tarsi impingement, was also evident in all patients. In gait analysis, walking with the feet in external rotation and the early heel off phase of the gait were characteristic (Fig. 1).

The preoperative and postoperative radiological assessment and measurements and the video editing were made by M.P. with the contribution of coauthor M.O. For the radiological measurements, we used A/P and lateral weightbearing views, which included the calcaneal inclination angle (calcaneal pitch angle), the talocalcaneal angle (Kite's angle), Meary's angle, the talar declination angle, and the talonavicular joint subluxation (mild <25, moderate 25% to 50%, severe >50%).

Preoperatively in lateral weightbearing views we noticed (Fig. 2) an increased Meary's angle, indicating talonavicular joint dorsal subluxation; a decreased calcaneal inclination angle, indicating longitudinal medial arch collapse; an increased talar declination angle, indicating a plantar deviation of the talus; and an increased talocalcaneal angle, indicating a plantar deviation of the talus. Correspondingly in A/P weightbearing views, we noticed (Fig. 3) an increased Meary's angle, indicating talonavicular joint lateral subluxation, with lateral displacement of the medial foot ray (navicular, medial cuneiform, first metatarsal, great toe); an increased talocalcaneal angle, indicating talus medial deviation with heel valgus position; and a talonavicular joint lateral subluxation (moderate 25% to 50%, severe >50%), with the talar head no longer covered medially by its articulation with the navicular (Table 1).

The clinical assessment was based on the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hind foot rating scale. To increase the credibility of the AOFAS rating scale in children, we additionally used for estimation of the severity of flatfoot deformity in each child a flatfoot sheet (Table 3), which included a patient complaints questionnaire and clinical and radiological assessment preoperatively and postoperatively.

The surgical treatment for flatfoot deformity correction started with triple-hemisection percutaneous Achilles tendon lengthening (Hoke technique) (24) (Fig. 4) and finished with arthroereisis subtalar implant implantation (Fig. 5). The surgical technique for arthroereisis was performed through a 1- to 2-cm skin incision over the sinus tarsi. The deep fascia was identified and bluntly dissected, allowing entrance into the sinus tarsi canal. It was important that minimal blunt dissection only was allowed to perform in the sinus tarsi. The probe instrument then was inserted through the sinus tarsi into the sinus canalis, from lateral to medial, until tenting was noted on the medial aspect of the foot. The probe should be positioned perpendicular to the lateral wall of the calcaneus, angled slightly posterior and superior. The probe moved in a clockwise and counterclockwise direction to slightly dilate the tarsal canal. The guide pin was then inserted into the sinus tarsi from lateral to medial until tenting was noted on the medial aspect of the foot. A small incision was made to allow passage of the guide pin through the medial aspect of the foot, just inferior to the tibialis posterior tendon, and anterior and slightly inferior to the medial malleolus. Subtalar joint abnormal eversion was always detected. The appropriate sizer should limit "abnormal" joint eversion. The appropriate size will allow the calcaneal subtalar joint complex to evert to approximately 2° to 4°. Intra-operative imaging, to evaluate the degree of correction and placement of the trial implant, was performed to determine

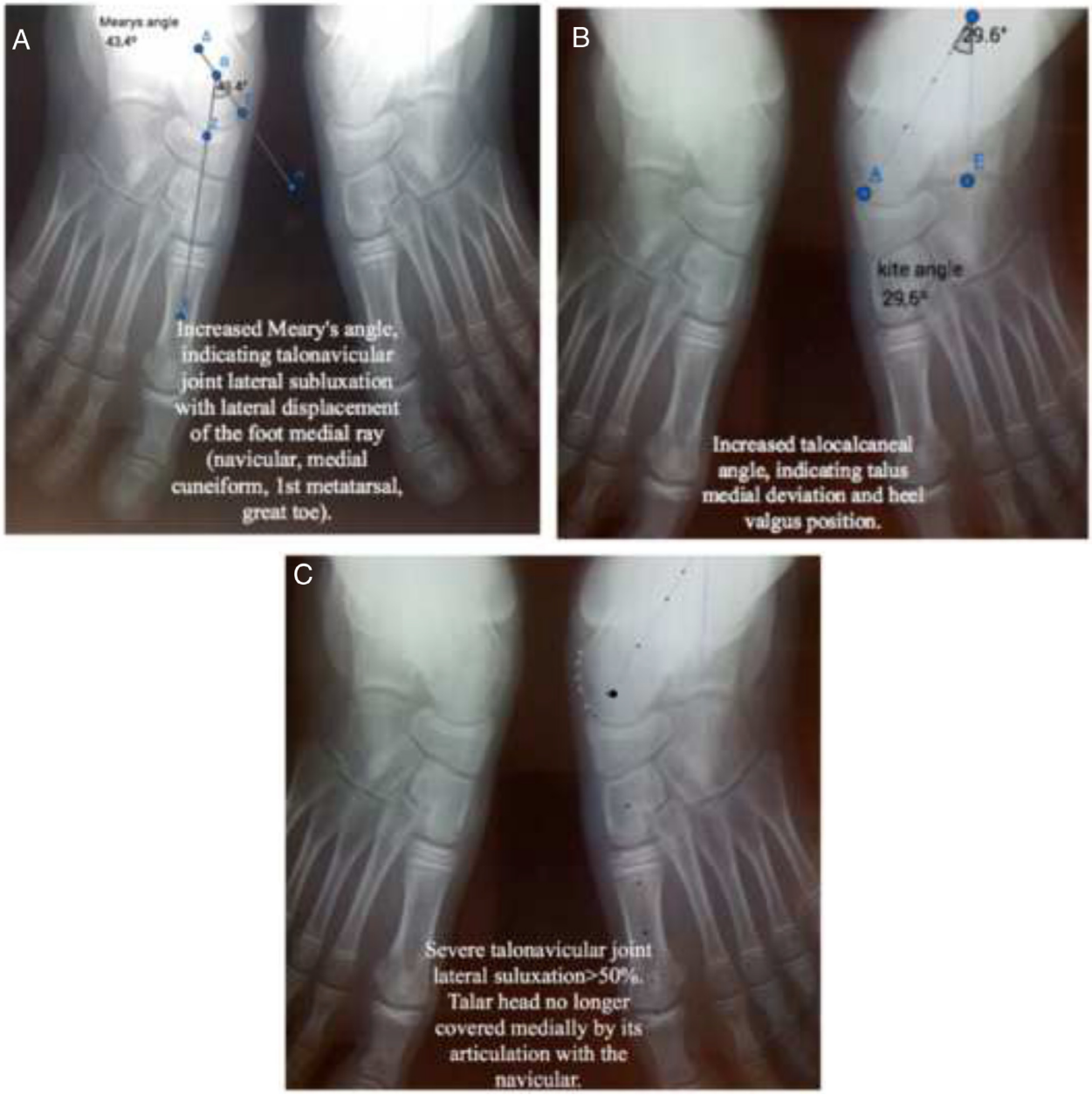

Fig. 3. (*A*) Radiograph weightbearing A/P view. Meary's angle increased, indicating talonavicular joint lateral subluxation, with lateral displacement of the medial foot ray (navicular, medial cuneiform, first metatarsal, great toe). (*B*) Radiograph weightbearing A/P view. Talocalcaneal angle increased, indicating talus medial deviation and a valgus heel position. (*C*) Radiograph weightbearing A/P view. Talonavicular joint lateral subluxation (severe >50%). Talar head no longer covered medially by its articulation with navicular. Patient ID 2 in Table 1.

the correct position on the A/P view, so that the leading edge of the trial implant should approach, but not cross, the longitudinal bisection of the talus (Fig. 6). The trailing edge of the implant should be at least 5 mm medial to the lateral wall of the calcaneus. The trial implant then removed, and the proper sized implant was inserted (Fig. 5). The appropriate size will allow 2° to 4° of subtalar joint eversion. Intraoperative imaging was essential for this procedure, to verify proper positioning of the implant (Fig. 6). The operation ended with guide pin removal and skin closure.

We recommend no weightbearing with a below-the-knee scotch cast for 2 weeks, followed by a below-the-knee walking scotch cast for another 2 weeks, and orthopedic insole below-the-knee brace for another 3 months**.** The purpose for these postoperative instructions is to give enough time to the soft tissues around the subtalar implant, into sinus tarsi, to grow and stabilize the subtalar implant, reducing the chances for sinus tarsi collapse and implant failure. All patients were followed up at 2 weeks, 4 weeks, 3 months, and 6 months, and thereafter at regular 6-month intervals until skeletal maturity.

The statistical analysis of our clinical and radiological results was performed by author M.P., with the contribution of the coauthor M.O., using the SPSS version 23.0 software (SPSS Inc., Chicago, IL). A paired *t* test was used to analyze data, and a *p* value of <.05 was considered statistically significant.

Results

A total of 14 (N = 14) patients were included in the analyses. Of these, 10 (71.42%) were males and 4 (28.57%) were females (Table 4.) There were 28 (100%) feet in the cohort, treated surgically, between 2012 and 2015, for symptomatic flexible flatfoot deformity with subtalar arthroereisis, with MBA subtalar implant (Integra implant) (Table 1). The mean age at surgery was 10.71 ± 1.58 (range 8 to 14) years (Table 5). The minimum follow-up duration was 19 months, with mean follow-up duration of 35.14 ± 9.82 (range 19 to 60) months (Table 2). Until now, no complications have been reported.

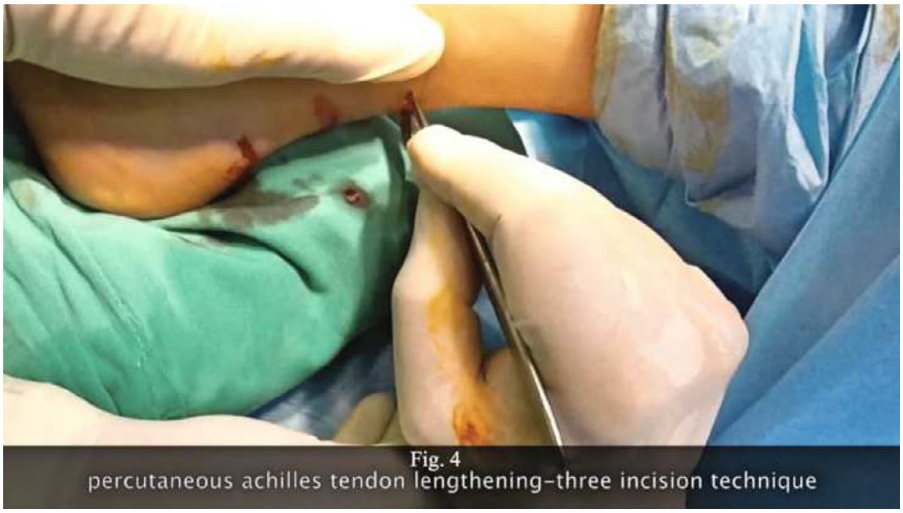

Fig. 4. Triple-hemisection percutaneous Achilles tendon lengthening by Hoke technique. Two lateral cuts and 1 medial cut.

Fig. 5. Arthroereisis surgical technique. (*A*) Skin incision over the sinus tarsi. (*B*) Probe insertion. (*C*) Guide pin insertion. (*D*) Guide pin insertion until tenting is noted on the medial aspect of the foot. (*E*, *F*) MBA implant implantation.

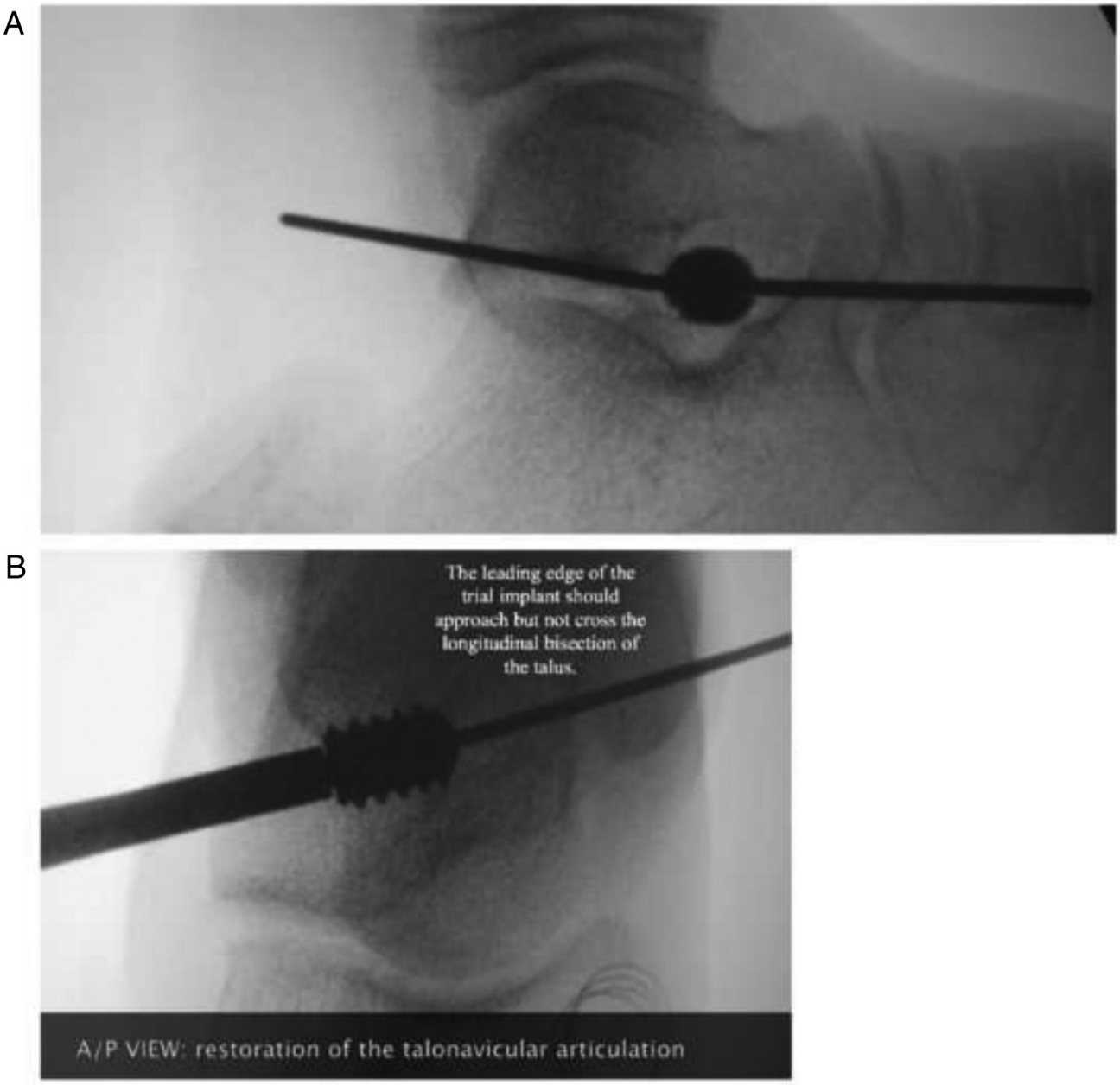

Fig. 6. (*A*) Intra-operative imaging to evaluate the degree of correction and placement of the trial implant. (*B*) The leading edge of the trial implant should approach, but not cross, the longitudinal dissection of the talus.

Based on the radiographic weightbearing results, the mean preoperative and postoperative weightbearing radiological features were as follows. The mean preoperative calcaneal inclination angle (Table 6) was 10.6° ± 2.61° (range 8° to 15.40°), and that postoperatively was 15.3° ± 1 (range 14° to 17.6°), with mean correction angle of 4° (calcaneal inclination angle improved slightly and still remaining below the normal angle range of 20° to 40°), indicating only mild restoration of the medial arch (Fig. 7). The mean preoperative Meary's angle in lateral view (Table 7) was 18.98° ± 6.59° (range 9.3° to 25°), and that postoperatively was 2.69° ± 0.47° (range 1.9° to 3.6°), with mean correction angle of 16.3° (Meary's angle lateral view reduced significantly), indicating the reduction of the dorsal subluxation of the talonavicular joint (Fig. 7). The mean preoperative Kite's angle lateral view (Table 9) was 46.55° ± 7.9° (range 35.6° to 53.7°), and that postoperatively was 31.4° ± 1° (range 30° to 33.5°), with mean correction angle of 15.1° (Kite's angle lateral view reduced significantly), indicating a lifting of

Table 4
Gender frequencies

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	10	71.4	71.4	71.4
Female	4	28.6	28.6	100.0
Total	14	100.0	100.0	

Table 5
Age frequencies (years)

N	
Valid	14
Missing	0
Mean	10.7143
Standard error of the mean	0.42489
Median	10.5000
Standard deviation	1.58980
Minimum	8.00
Maximum	14.00
Sum	150.00

Table 7
Meary's angle lateral view frequencies

	Meary's Angle Lateral View Preoperative	Meary's Angle Lateral View Postoperative
N		
Valid	14	14
Missing	0	0
Mean	18.9857	2.6929
Standard deviation	6.59042	0.47469
Range	15.70	1.70
Minimum	9.30	1.90
Maximum	25.00	3.60

Table 6
Calcaneal inclination angle

	Calcaneal Inclination Angle Preoperative	Calcaneal Inclination Angle Postoperative
N		
Valid	14	14
Missing	0	0
Mean	10.6643	15.3714
Standard deviation	2.61581	1.09434
Range	7.40	3.60
Minimum	8.00	14.00
Maximum	15.40	17.60

Table 8
Meary's angle a/p view frequencies

	Meary's Angle A/P View Preoperative	Meary's Angle A/P View Postoperative
N		
Valid	14	14
Missing	0	0
Mean	33.7857	5.1143
Standard deviation	11.45431	2.95136
Range	26.50	7.90
Minimum	17.60	0.00
Maximum	44.10	7.90

Abbreviations: A/P, anteroposterior.

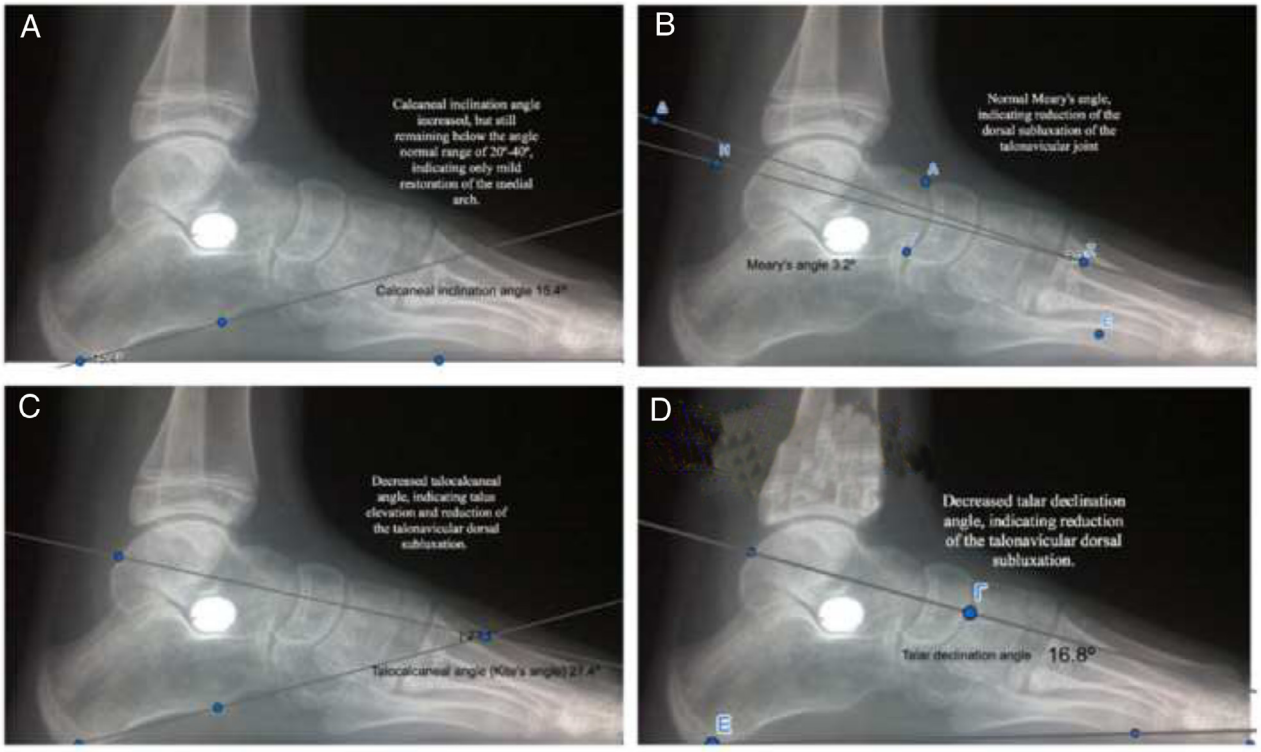

Fig. 7. Radiographs, weightbearing lateral views. (*A*) Postoperative calcaneal inclination angle improved slightly and still remaining below the normal angle range of 20° to 40°, indicating only mild restoration of the medial arch. (*B*) Postoperative Meary's angle decreased, indicating the elevation of the talus and reduction of the dorsal subluxation of the talonavicular joint at the same time. (*C*) Postoperative Kite's angle decreased, indicating the elevation of the talus and reduction of the dorsal subluxation of the talonavicular joint at the same time. (*D*) Postoperative talar declination angle decreased, indicating the elevation of the talus and reduction of the dorsal subluxation of the talonavicular joint at the same time. Patient ID 2 in Table 1.

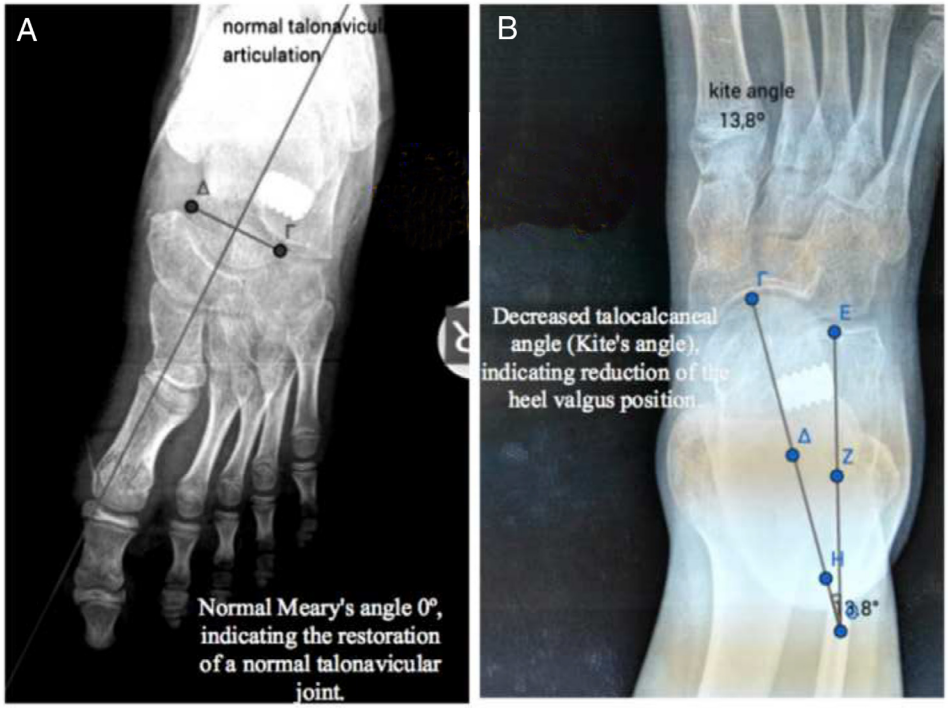

Fig. 8. (*A*) Radiograph, weightbearing A/P view. Postoperative Meary's angle decreased, indicating a reduction of the talonavicular joint lateral subluxation. (*B*) Radiograph, weightbearing A/P view. Postoperative Kite's angle decreased, indicating a reduction of the valgus heel position. Patient ID 2 in Table 1.

Table 9
Kite's angle lateral view frequencies

	Kite's Angle Lateral Preoperative	Kite's Angle Lateral Postoperative
N		
Valid	14	14
Missing	0	0
Mean	46.5571	31.4286
Standard deviation	7.90985	1.00263
Range	18.10	3.50
Minimum	35.60	30.00
Maximum	53.70	33.50

Table 10
Kites angle a/p view frequencies

	Kite's Angle A/P Preoperative	Kite's Angle A/P Postoperative
N		
Valid	14	14
Missing	0	0
Mean	34.7286	20.4429
Standard deviation	5.66805	3.76884
Range	17.40	12.00
Minimum	28.40	13.80
Maximum	45.80	25.80

Abbreviation: A/P, anteroposterior.

Table 11
Talar declination angle frequencies

	Talar Declination Angle Preoperative	Talar Declination Angle Postoperative
N		
Valid	14	14
Missing	0	0
Mean	31.7929	17.7000
Standard deviation	5.28386	0.86913
Range	13.50	3.20
Minimum	23.30	16.20
Maximum	36.80	19.40

Table 12
Talonavicular subluxation

Talonavicular subluxation	Frequency	Percent	Valid Percent	Cumulative Percent
Preoperative				
Moderate subluxation, 25% to 50%	5	35.7	35.7	35.7
Severe subluxation, >50%	9	64.3	64.3	100.0
Total	14	100.0	100.0	
Postoperative				
Normal talonavicular articulation	5	35.7	35.7	35.7
Mild subluxation, <25%	9	64.3	64.3	100.0
Total	14	100.0	100.0	

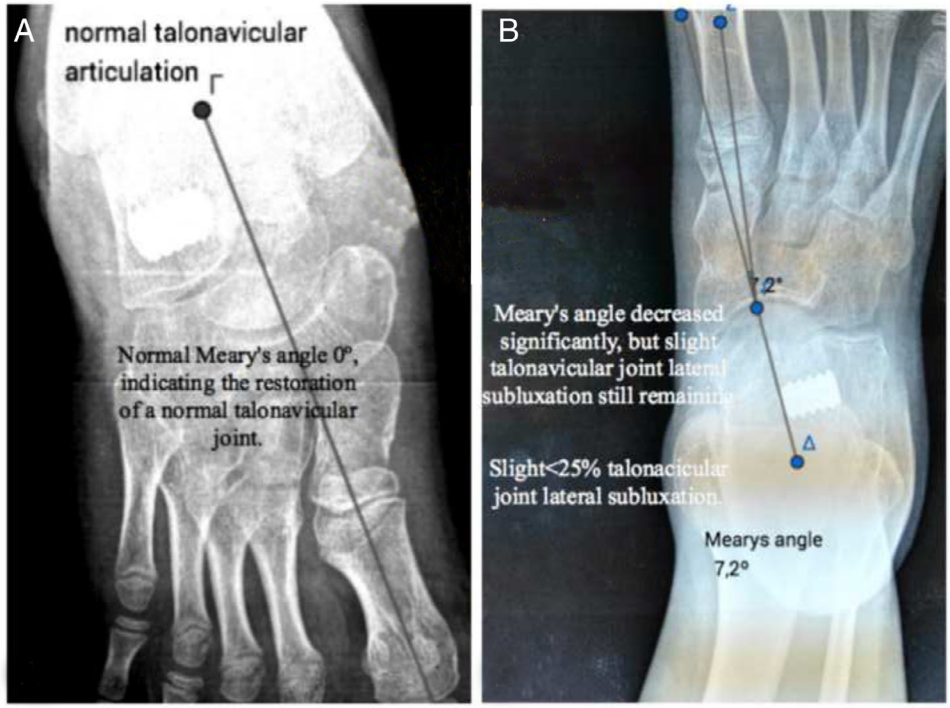

Fig. 9. (*A*) Radiograph, weightbearing A/P view. Postoperative reduction of the moderate talonavicular subluxation to normal talonavicular articulation. (*B*) Radiograph, weightbearing A/P view. Postoperative reduction of the severe talonavicular subluxation to slight talonavicular subluxation. Patient ID 2 in Table 1.

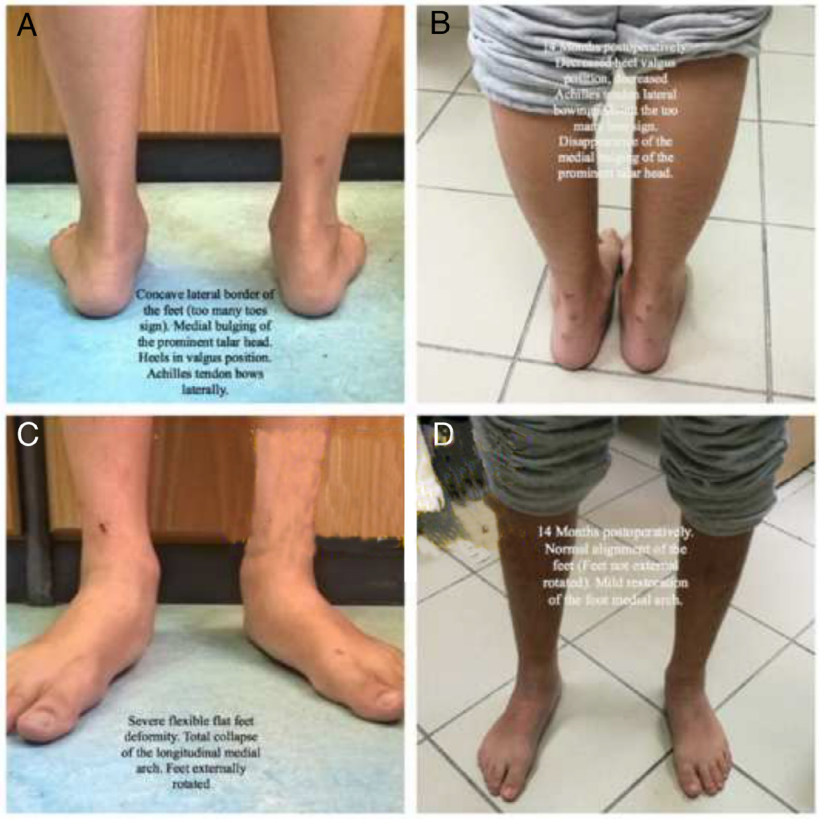

Fig. 10. Posterior view image of the feet, preoperatively (A) and 14 months postoperatively (B), following subtalar arthroereisis in association with percutaneous triple-hemisection Achilles tendon lengthening, for correction of severe flexible flatfoot deformity. Photo showing greatly decreased heel valgus position, decreased lateral bowing of the Achilles tendon, no too-many-toes sign, and disappearance of the medial bulging of the preoperative prominent talar head. Frontal view image of the feet, preoperatively (C) and 14 months postoperatively (D), following subtalar arthroereisis in association with percutaneous triple-hemisection Achilles tendon lengthening, for correction of severe flexible flatfoot deformity. Photo showing restoration of a normal alignment of the feet (feet not external rotated), but showing only mild restoration of the medial arch.

Table 13
AOFAS score frequencies

Statistics	AOFAS Score Preoperative	AOFAS Score Postoperative
N		
Valid	14	14
Missing	0	0
Mean	65.1429	88.8571
Standard deviation	7.16677	5.61395
Range	17.00	14.00
Minimum	58.00	83.00
Maximum	75.00	97.00

Abbreviation: AOFAS, The American Orthopedic Foot and Ankle Society.

the talus in a more horizontal position. The mean preoperative Kite's angle lateral view (Table 9) was 46.55° ± 7.9° (range 35.6° to 53.7°), and that postoperatively was 31.4° ± 1° (range 30° to 33.5°), with mean correction angle of 15.1° (Kite's angle lateral view reduced significantly), indicating a lifting of the talus in a more horizontal position (Fig. 7). The mean preoperative talar declination angle (Table 11) was 31.79° ± 5.28° (range 23.3° to 36.8°), and that postoperatively was 17.7° ± 0.86° (range 16.2° to 19.4°), with mean correction angle of 14° (talar declination angle reduced significantly), indicating a lifting of the talus in a more horizontal position. The mean preoperative talar declination angle (Table 11) was 31.79° ± 5.28° (range 23.3° to 36.8°), and that postoperatively was 17.7° ± 0.86° (range 16.2° to 19.4°), with mean correction angle of 14° (talar declination angle reduced significantly), indicating a lifting of the talus in a more horizontal position (Fig. 7). The mean preoperative Meary's angle in A/P view (Table 8) was 33.78° ± 11.45° (range 17.6° to 44.1°), and that postoperatively was 5.1° ± 2.95° (range 0° to 7.9°), with mean correction angle of 28.6° (Meary's angle A/P view reduced significantly), indicating reduction of the lateral subluxation of the talonavicular joint (Fig. 8). The mean preoperative Kite's angle A/P view (Table 10) was 34.72° ± 5.66° (range 28.4° to 45.8°), and that postoperatively was 20.44° ± 3.76° (range 13.8° to 25.8°), with mean correction angle of 14.3° (Kite's angle A/P view reduced significantly), indicating reduction of the heel valgus position (Fig. 8). Preoperatively, the talonavicular subluxation (Table 12) was severe (>50%) in 64.3% of our patients, and moderate (25% to 50%) in 35.7%. Postoperative restoration of a normal talonavicular joint was achieved in 35.7% (Figs. 9), and significant reduction of the severe talonavicular joint subluxation to mild (<25%) was achieved in 64.3% (Fig. 9) of the patients. Postoperatively, the flatfoot deformity correction was obvious clinically, with decreased heel valgus position, decreased lateral bowing of Achilles tendon, and greatly decreased talonavicular joint subluxation (Fig. 10). Additionally, the radiological findings proved that arthroereisis helped the reduction of the subtalar and talonavicular joint, by driving the heel back to its normal neutral position, and by driving at the same time the medial foot ray (navicular, medial cuneiform, first metatarsal, great toe) medially, back to its normal position. With arthroereisis, there was only a slight improvement in the restoration of the medial arch clinically (Fig. 10) and radiologically.

The mean preoperative AOFAS score (Table 13) was 65.14 ± 7.16 (range 58 to 75) points. The mean postoperative AOFAS score 1 year after the operation was 88.85 ± 5.61 (range 83 to 97) points. The mean AOFAS ankle-hind foot score improved by 23.7 points. The 2-tailed p value <.0001 (Table 14) was statistically significant with $t = 45.770$ and degrees of freedom 13. After arthroereisis surgical treatment, all AOFAS scores and all foot angles improved significantly, except calcaneal inclination angle, which improved slightly, indicating only mild restoration of the medial arch. The AOFAS hindfoot score correlated positively with all the foot angles, including the calcaneal inclination angle.

Discussion

First, the purpose of this study was to recognize those young patients with symptomatic, flexible flatfoot deformity who need treatment. Second, we wished to provide radiological and clinical evidence that arthroereisis was capable, in these children with symptomatic flatfoot deformity, to relocate the talus properly over the calcaneus at the subtalar joint, to allow remodelling of these bones during the rest of their growing period, and to correct the dorsal and lateral subluxation of the talonavicular joint, driving the navicular bone in its normal position at the talonavicular articulation. To minimize the complication rate in arthroereisis, we need to emphasize one more time, the importance of performing only minimal blunt dissection in the sinus tarsi, and the selection of the proper size of the inserted subtalar implant.

In conclusion, after arthroereisis surgical treatment, all AOFAS scores and all foot angles (except the calcaneal inclination angle, which improved slightly, indicating only mild restoration of the medial arch) improved significantly. The AOFAS hindfoot score correlated positively with all the foot angles, including the calcaneal inclination angle. However, despite our appreciation of the limitations of our investigation, we believe that the results of reconstructive flatfoot surgery that combined subtalar arthroereisis with a barrel-shaped implant and Achilles' tendon lengthening resulted in favorable clinical and radiological outcomes and patient satisfaction. The subtalar arthroereisis is a minimally invasive procedure that can be used in the surgical treatment of children with symptomatic flexible flatfoot deformity.

Table 14
Paired samples test

	Paired Differences							
	Mean	Standard Deviation	Standard Error of the Mean	95% Confidence Interval of the Difference		t	Degrees of freedom	Significance (2-tailed)
Pair				Lower	Upper			
AOFAS score postoperative/preoperative	23.71429	1.93862	.51812	22.59496	24.83361	45.770	13	.000

Abbreviation: AOFAS, The American Orthopedic Foot and Ankle Society.

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