Comparativestudy between the calcaneo stop procedure and endorthesis in the management of pediatric symptomatic flexible flatfoot

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Purpose
The aim of the study was to compare the results of using the calcaneo stop procedure and endorthesis in the management of symptomatic flexible flatfoot (FFF) in pediatrics.
Patients and methods
This is a prospective randomized study using the closed envelope technique. It was conducted on 30 feet of 19 patients admitted in the National Institute of Neuromotor System. All cases presented with symptomatic flexible pes planovalgus. The current study started in May 2020 and ended in January 2022. Written detailed informed consents were obtained from parents. Inclusion criteria were age 7–14 years, symptomatic idiopathic FFF, failed conservative treatment, and no previous foot surgery. Exclusion criteria were children young than 7 years or older than 14 years, rigid flatfeet, asymptomatic FFF, patients with major congenital malformations, severe neurological disorders, patients with neuromuscular disorders, patients subjected to other foot surgery, and patients with traumatic flatfeet. The patients were randomly assigned into two groups: group 1 included 15 feet of nine patients (six bilateral and three unilateral) who underwent the calcaneo stop technique, and group 2 included 15 feet of 10 patients (five bilateral and five unilateral) who underwent endorthesis by subtalar fit implant. The mean age of group 1 was 9.90±2.86 years (range, 7–14 years), whereas of group 2 was 9.70±1.50 years (range, 8–14 years). There were 10 male patients (five underwent calcaneo stop and five endorthesis) and nine female patients (five underwent calcaneo stop and four endorthesis). The right foot was operated upon in 16 cases, and the left foot was operated upon in 14 cases. The average AOFAS preoperative score in group 1 was 68.7±5.7 (range, 58–78), which was subdivided into 6.7% with good score and 86.3% with fair score, whereas in group 2, it was 70.13±5.5 (range, 58–78), which was subdivided into 26.8% with good score and 73.2% with fair score.
Results
There were statistically significant improvements in both groups, with no difference in their outcomes. Both groups showed significantly improved hindfoot and midfoot motion and positioning. Hindfoot range of motion was preserved. Radiography also revealed significant improvements.
Conclusion
Both procedures are valid options for the surgical management of idiopathic symptomatic flatfoot in pediatric patients.

Keywords:
calcaneo stop, endorthesis, flexible flatfoot, pediatric

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Introduction

Flatfoot is one of the most common conditions seen in the pediatric orthopedic practice. The first priority in evaluating children with flatfeet is to separate those in whom the natural history of the disorder will result in pain or disability as an adult from those in whom the abnormality has a benign prognosis. A useful method of evaluation is to categorize these patients as having flexible or nonflexible flatfoot, and then as having a painful or nonpainful foot [1].

Flexible flatfoot (FFF) is a normal foot shape that is present in most infants and many adults. The arch elevates spontaneously in most children during the first decade of life. There is no evidence that a longitudinal arch can be created in a child's foot by any external forces or devices [2].

The incidence of flatfoot is ~2.7–18% in children [2,3]. FFF is characterized by the normal architecture of the medial longitudinal arch during nonweight bearing and flattening of the arch during stance or weight bearing [3,4].

FFF may be symptomatic or asymptomatic. Symptomatic forms of FFF produce subjective and objective complaints, including pain along the medial side of the foot, sinus tarsi, leg, and knee. Flatfoot decreases endurance and leads to gait disturbances [3]. Pronation of the subtalar joint during the propulsive phase of gait is mostly responsible for major deformities in adult life [5].

Flatfoot may also lead to hallux valgus, metatarsalgia, tarsal tunnel syndrome, posterior tibial tendon dysfunction, and osteoarthritis of the subtalar and midtarsal joints [6,7].

The treatment options vary from the use of an orthosis to arthrodesis. First, conservative methods (corrective shoes, arc supports, heel-wedges, etc.) should be applied, and when these are insufficient in relieving the patient's symptoms (mainly the pain during daily routine activities), then surgical procedures should be performed. However, especially in idiopathic cases, it is best to think twice before deciding to perform surgery, as the disorder is of a benign nature.

Surgical options vary from simple soft tissue procedures (lengthening of the heel cord, tendon transfers, etc.) to tarsal osteotomies, arthroereisis, subtalar extra-articular arthrodesis, and triple arthrodesis. When these are compared, all techniques have advantages and disadvantages, but it is not possible to consider certain indications for the techniques [8,9].

Soft tissue reconstruction of the FFF is rarely successful as an isolated procedure and should always be combined with bony procedures or arthroereisis [10]. Excellent results from the reconstructive bony procedures of flatfoot have been reported. However, the long-term results are not satisfactory [11].

Arthrodesis (extra-articular subtalar arthrodesis for symptomatic planovalgus feet and triple arthrodesis for failed surgical treatment) provides a stable foot and durable correction. However, this procedure transfers energy to the nonfused adjacent joints, which may lead to early arthritis [12,13].

Arthroereisis limits subtalar joint pronation through insertion of an implant or material into the sinus tarsi [14,15]. The presence of an implant achieves correction by stimulating the proprioceptive foot receptors, allowing for normal subtalar joint motion [16], while blocking excessive movement. Different shapes and implant designs have been proposed, including bone grafts, polyethylene, silicone, bioresorbable materials, and metallic implants [17].

Hence, the purpose of this study was to compare the result of using the calcaneo stop procedure and endorthesis in the management of symptomatic FFF in pediatric.

Patients and methods

This is a prospective randomized study using the closed envelope technique. It was conducted on 30 feet (19 patients) admitted in the National Institute of Neuromotor System. All cases presented with symptomatic flexible pes planovalgus. The current study started in May 2020 and ended in January 2022. Written detailed informed consents were obtained from parents. Inclusion criteria were age 7–14 years, symptomatic idiopathic FFF, failed conservative treatment, and no previous foot surgery. Exclusion criteria were children younger than 7 years or older than 14 years, rigid flatfeet, asymptomatic FFF, patients with major congenital malformations, patients with severe neurological disorders, patients with neuromuscular disorders, patients subjected to other foot surgery, and patients with traumatic flatfeet. The patients were randomly assigned into two groups:

(1) Group 1: it included 15 feet of nine patients (six bilateral and three unilateral) who underwent the calcaneo stop technique.
(2) Group 2: it include 15 feet of 10 patients (five bilateral and five unilateral) who underwent endorthesis by subtalar fit implant.

Human and animals rights all procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This study was approved by the local ethical committee.

Informed consent Informed consent was obtained from all the parents of the individual participants included in the study, since it was per-formed on underage patients.

The mean age in group 1 was 9.90 ± 2.86 years (range, 7–14 years), whereas in group 2 was 9.70 ± 1.50 years (range, 8–14 years).

There were 10 male patients (five underwent calcaneo stop and five endorthesis) and nine female patients (five underwent calcaneo stop and four endorthesis).

The right foot was operated upon in 16 cases, and the left foot was operated upon in 14 cases. The average AOFAS preoperative score in group 1 was 68.7 ± 5.7 (range, 58–78), which was subdivided into 6.7% with good score and 86.3% with fair score, whereas in group 2 was 70.13 ± 5.5 (range, 58–78),

which was subdivided into 26.8% with good score and 73.2% with fair score.

Surgical approaches

(1) Surgical treatment was performed under general anesthesia.
(2) A tourniquet was applied proximally to the lower limbs.
(3) Patients were placed in a supine position.

Calcaneo-stop procedure

(1) A 2-cm incision was made under the skin lines on the lateral aspect of the sinus tarsi (Fig. 1). Soft tissue dissection was performed bluntly, taking care to avoid the sural nerve. Then, under radiographic control, a guide wire was inserted vertically in the calcaneus from superior to inferior opposite to the sinus tarsi after reduction of the subtalar eversion (Fig. 1), followed by guide wire overdrilling with a 3.2-mm drill bit and then insertion of a 6.5-mm cancellous screw with a length of 30–35 mm as a calcaneal-stop screw, so that the screw head impinges against the lateral aspect of the talus preventing eversion at the subtalar joint (Fig. 1) (allowing only up to 4° of the normal valgus range of motion; the angle formed by a line bisecting the calf with another line bisecting the heel vertically while pressing over the plantar aspect of the fourth and fifth metatarsal heads).

Endorthesis

(1) An ~2-cm incision was made through the sinus tarsi (Figs 2 and 3). Deep fascia and the capsule covering the tarsal sinus were incised using blunt dissection. The tarsal sinus was extended using a probe, and the subtalar joint axis was determined. A guide wire was advanced from lateral to medial through the tarsal tunnel (Fig. 2). Tester implants were placed through the guide wire to choose the most suitable implant (Fig. 2), and the range of motion of the posterior foot was assessed. A suitable implant was then placed, and the location of the implant was confirmed (Fig. 2). The incision site was closed routinely. There was no other procedure performed in the same sitting.

Patients of both techniques (both groups) were followed for the following:

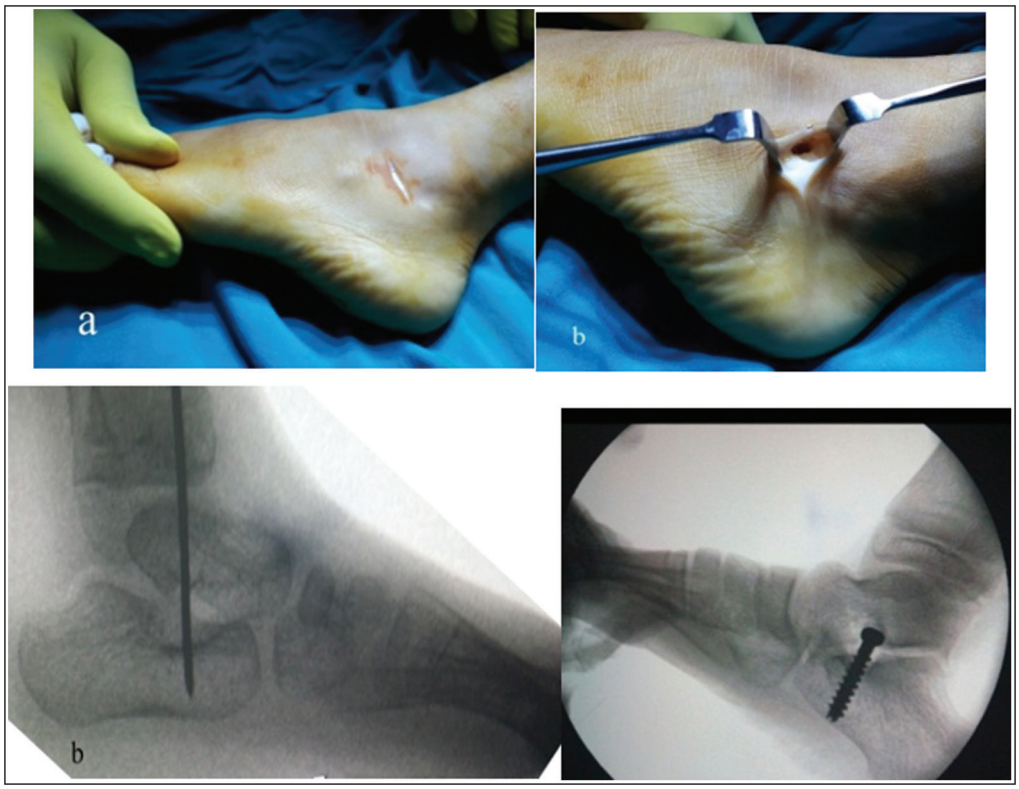
(1) The foot was assessed intraoperatively for improved talonavicular coverage and recreation of a satisfactory medial arch.
(2) Wound closure.

Postoperative management

Calcaneo stop

(1) Patients were placed in below-knee walking cast for 3 weeks to minimize possible implant loosening.

Figure 1



Intraoperative photographs showing surgical steps of the calcaneo stop technique.

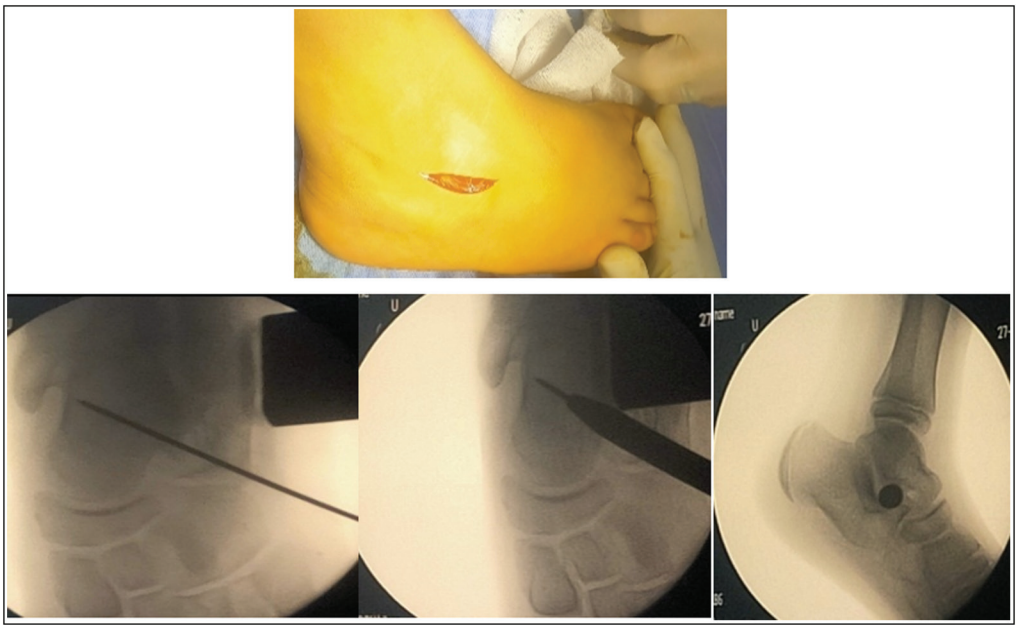
Following cast removal, unrestricted activities were encouraged.

(2) There was no intention to remove screws unless there are complications requiring that removal (Fig 4).

Endorthesis

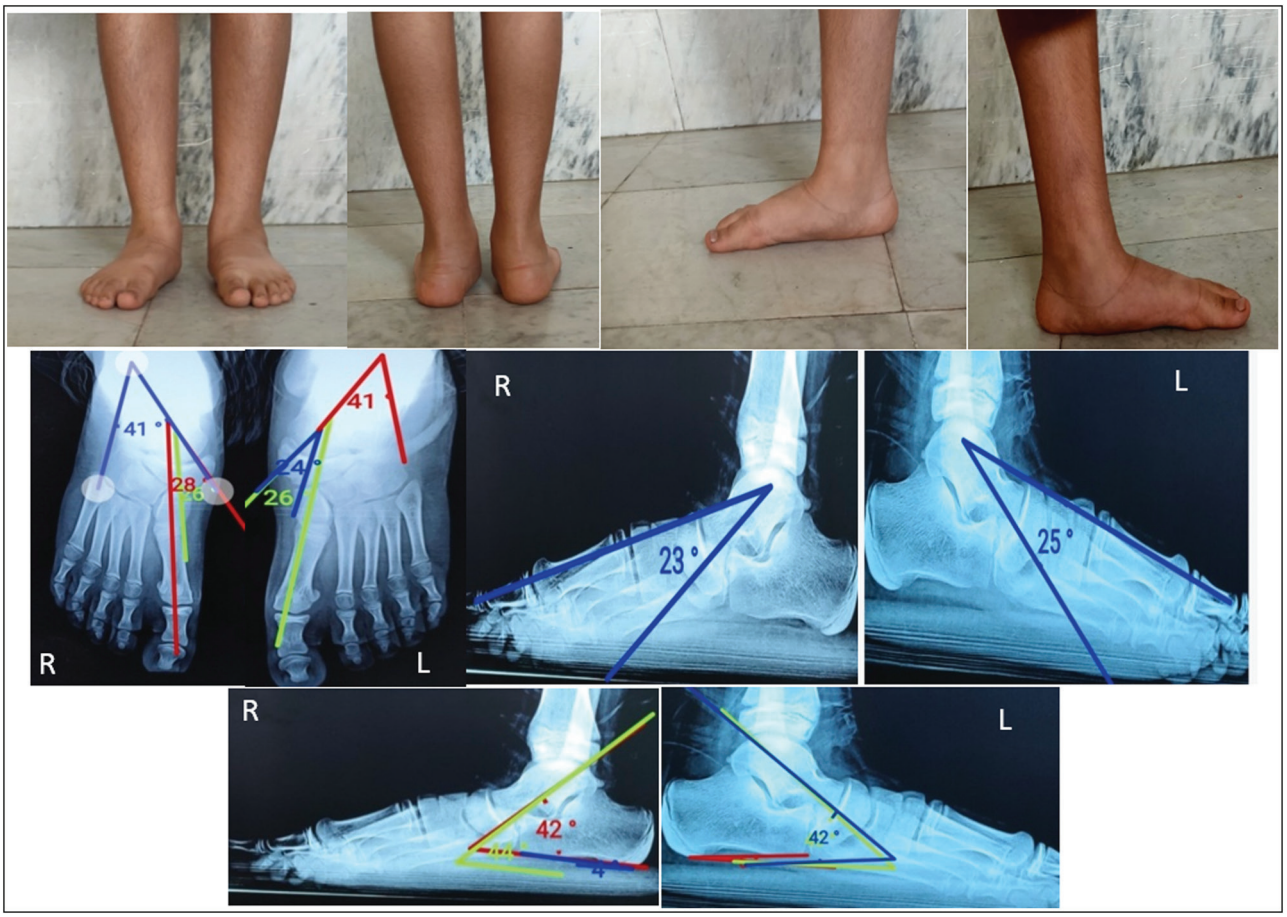
(1) Postoperatively, a below-knee cast was applied and retained for 3 weeks.
   (a) Postoperative assessment and follow-up regimen:

Figure 2



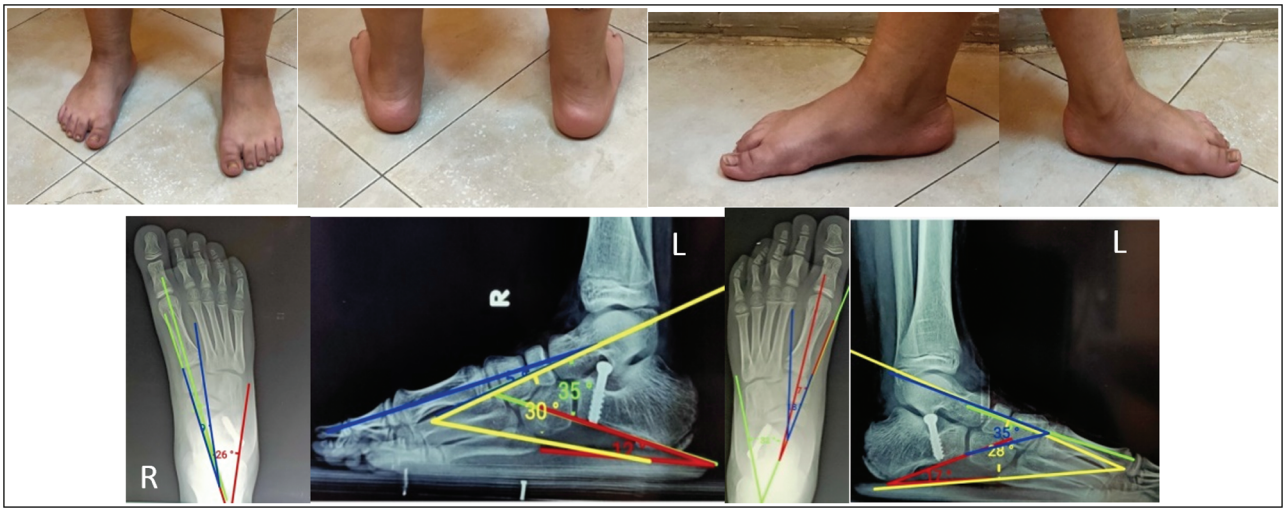
Intraoperative photographs showing surgical steps of the endorthesis procedure.

Figure 3



Preoperative radiographic and clinical photographs before calcaneo stop procedure.

Figure 4



Postoperative radiographic and clinical photographs after calcaneo stop procedure.

The follow-up period ranged from 6 to 9 months (average 8 months). All cases were assessed clinically and radiographically 6 months postoperatively, and comparison between the two groups was done regarding the following outcomes:

(1) Primary outcomes (most important outcomes that were assessed):
   (a) Improvement in clinical outcome by the clinical score proposed by Yoo *et al* [18] (Table 1) at 6 months postoperatively) in the two techniques (comparing both techniques):
      (i) For forefoot abduction and hindfoot valgus, the results were assessed as follows:
         (1) 'Normalized' when the normal neutral alignment of the forefoot or hindfoot developed in weight-bearing position.
         (2) 'Improved' when the corrected amount of each parameter reached 50% or more of the preoperative angular deformity.
         (3) 'Minimal' when less than 50%.
      (ii) For symptomatic relief, it was assessed by the subjective report of the patients or their parents.
      (iii) For the longitudinal arch, the results were assessed as follows:
         (1) 'Normalized' when a marked longitudinal arch developed in weight-bearing position.
         (2) 'Improved' when the medial aspect of the foot was off the ground in weight-bearing position.
         (3) 'Minimal' when the arch developed only in nonweight-bearing position.

When the total score is 8 or more, the results were considered satisfactory [18].

   (b) Improvement in postoperative radiographic measurements (comparing both techniques):

Calcaneo stop group: patients were followed up on the first postoperative day and then after 2, 4, and 6 months by standing foot radiograph.

Endorthesis group: patients were followed up on the first postoperative day and then at 6 weeks, 8 weeks, 4 months, and 6 months by standing foot radiograph.

The same angles that were measured preoperatively were measured at the 6-month-follow-up radiograph, to be compared with the preoperative ones.

ϖBosch Aufmaßkamera (Bosch Aufmaßkamera de.convisual. bosch.measuringcamera-1.3–7.apk) android application was used for the measurement of all angles, which were measured by the first author.

(2) Secondary outcome parameters (other outcomes that were assessed 6 months postoperatively):
   (a) Patient satisfaction.
   (b) Tolerance to shoes.

Statistical analysis

Data processing

(1) Variables were coded for proper extraction of data.
(2) Computerized data entry was done.

Statistical analysis of data

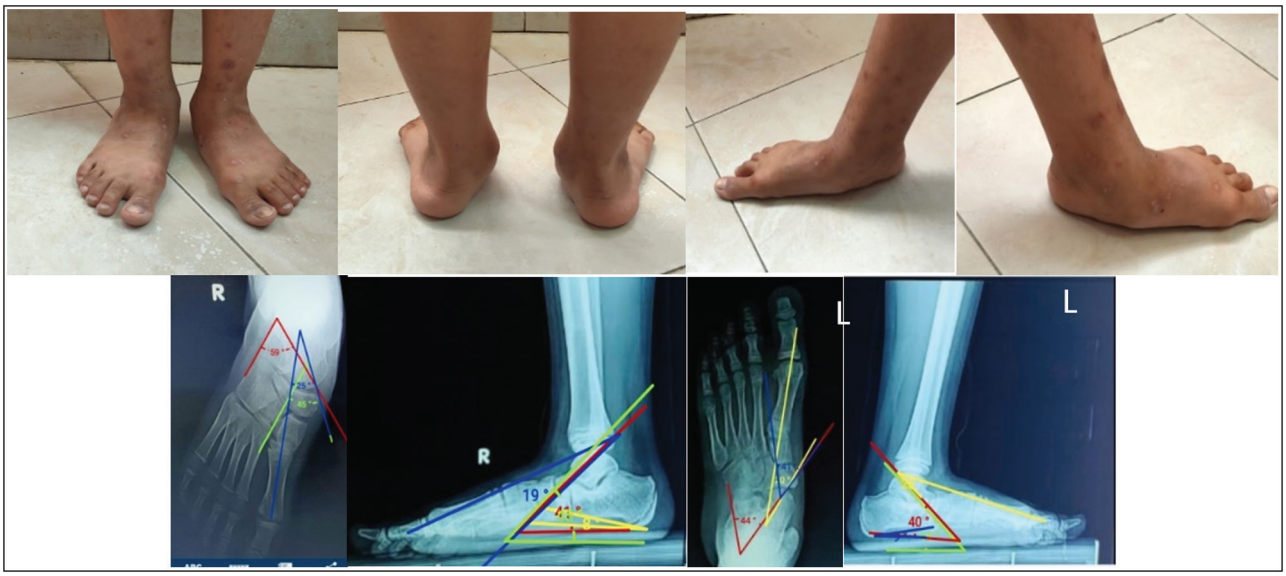
Statistical analysis was carried out using the SPSS computer package, version 25.0 (IBM SPSS Statistics for Windows, Version 25.0.; IBM Corp., Armonk, New York, USA).

Table 1 Criteria for scoring clinical outcomes [18]

Points	Pain or Callus	Forefoot Abduction	Longitudinal Arch	Hindfoot Valgus
3	None	Normalized	Normalized	Normalized
2	Improved	Improved	Improved	Improved
1	Minimal change	Minimal change	Minimal change	Minimal change
0	Persistent	No change/Overcorrection/Recurrence		

Satisfactory=8–12 points; unsatisfactory=0–7 points.

Figure 5



Preoperative radiographic and clinical photographs before endorthesis procedure.

The collected data were statistically managed as follows:

(1) For descriptive statistics, the mean±SD, mean difference, median, minimum and maximum were used for quantitative variables, whereas the number and percentage were used for qualitative variables.

(2) For analytic statistics, χ^2 test was used to assess the differences in frequency of qualitative variables, whereas Fisher's exact test was used if any expected cell value in a 2×2 table was less than 5.

(3) To assess the differences in means of quantitative variables between both groups, independent samples *t* test was applied, whereas paired samples *t* test was used to compare the differences in means of quantitative variables in the same group.

(4) The statistical methods were verified, assuming a significant level of *P* value less than 0.05 and a highly significant level of *P* value less than 0.001 (Fig. 5).

Results

In total, 19 patients (30 feet) were included in this study. Demographic data and functional disability of the two groups are stated in Tables 2 and 3. The follow-up period ranged from 6 to 9 months (average 8 months). There was no statistically significant difference between the follow-up durations for the two groups. There was a statistically significant improvement in both primary and secondary outcome parameters after both procedures in

Table 2 Demographic data of calcaneo stop group

Parameter	Calcaneo stop
Feet	15/30 (50%)
Patients	10/19 (53.1%)
Age	9.90±2.87 y
Gender	5 males (50%)
	5 females (50%)
Bilateral	5 pts (50%)
Unilateral	5 pts (50%)
Side	8 Rt feet (53.3%)
	7 Lt feet (46.7%)

Table 3 Demographic data of the endorthesis group

Parameter	Endorthesis
Feet	15/30 (50%)
Patients	9/19 (46.9%)
Age	9.70±1.21 y
Gender	5 males (55.5%)
	4 females (45.5%)
Bilateral	6 pts (66.66%)
Unilateral	3 pts (33.33%)
Side	8 Rt (53.3%)
	7 Lt (46.7%)

comparison with the preoperative parameters. In group 1, the final AOFAS hind foot/ankle score at the time of maximal follow-up had an average score of 95.07 ± 4.34 (range, 86–100), which was subdivided in to 13.3% with good score and 73.7% excellent score, whereas in group 2 was 95.73 ± 3.61 (range, 86–100), which was subdivided in to 6.7% with good score and 86.3% excellent score. Regarding the clinical results, there were no statistically significant differences between the two groups regarding the total score (Table 4) (*P*=0.878).

(1) In group 1, 12 (73.3% of cases) feet showed excellent results, two (13.3%) feet showed good results, and two (13.3%) feet showed fair results, with no unsatisfactory results.
(2) In group 2: 10 (66.7%) feet of cases showed excellent results and five (33.3%) feet showed good results.
(3) Regarding the radiological results, both procedures showed statistically significant improvement in all angles compared with the preoperative angles (Tables 5 and 6). Comparing both techniques, there was no statistically significant difference for all angles.

Table 4 Comparison between the two groups regarding the change of each component of the clinical score

Clinical parameters	Points		Procedure [*n* (%)]		*P* value
			Calcaneo stop (*N*=15)	Endorthesis (*N*=15)	
Pain or callus	3	None	15 (100.0)	14 (93.3.0)	
	2	Improved	0	1 (6.7)	0.326
	1	Minimal change	0	0	
	0	Persistent	0	0	
Forefoot abduction	3	Normalized	13 (86.7)	11 (73.3)	
	2	Improved	1 (6.7)	4 (26.7)	
	1	Minimal change	1 (6.7)	0	0.724
	0	No change/overcorrection/recurrence	0	0	
Longitudinal arch	3	Normalized	8 (53.3)	10 (66.7)	
	2	Improved	5 (33.3)	5 (33.3)	
	1	Minimal change	2 (13.3)	0	0.252
	0	No change/overcorrection/recurrence	0	0	
Hindfoot valgus	3	Normalized	12 (80.0)	11 (73.3)	
	2	Improved	3 (20.0)	3 (20.0)	
	1	Minimal change	0	1 (6.7)	0.493
	0	No change/overcorrection/recurrence	0	0	

Table 5 Correction power of calcaneo stop preprocedure and postprocedure showing significant improvement of all angles

Variables	Calcaneo stop group		Diff (mean±SD)	*P* value
	Pre (mean±SD)	Post (mean±SD)		
TNCA°	32.60 ± 8.08	9.93 ± 14.733	22.67 ± 15.472	<0.001*
AP T-1$^{ST°}$	22.93 ± 7.601	3.53 ± 13.622	19.40 ± 11.728	<0.001*
AP TCA°	35.40 ± 7.169	22.73 ± 6.964	12.67 ± 6.651	<0.001*
LAT T-1$^{ST°}$	18.67 ± 7.934	4.40 ± 6.905	14.27 ± 6.850	<0.001*
LAT TCA°	42.60 ± 6.069	30.33 ± 7.556	12.27 ± 8.916	<0.001*
TDA°	40.13 ± 13.081	22.33 ± 7.403	17.80 ± 13.127	<0.001*
CPA°	3.74 ± 9.768	10.40 ± 5.011	-6.93 ± 6.933	<0.002*

Mean pre, preoperative mean value of angle; mean post, postoperative mean value of angle; Diff=mean correction power of angle.
*Significant.

Table 6 Correction power of endorthesis preprocedure and postprocedure showing significant improvement of all angles

Variables	Endorthesis group		Diff (mean±SD)	*P* value
	Pre (mean±SD)	Post (mean±SD)		
TNCA°	32.13 ± 12.011	11.60 ± 10.875	20.533 ± 11.470	<0.001*
AP T-1$^{ST°}$	24.47 ± 12.340	7.67 ± 9.371	18.800 ± 12.219	<0.001*
AP TCA°	35.60 ± 11.217	19.07 ± 8.924	16.533 ± 8.626	<0.001*
LAT T-1$^{ST°}$	24.27 ± 16.364	5.47 ± 7.472	18.800 ± 13.305	<0.001*
LAT TCA°	42.60 ± 8.943	33.47 ± 7.577	9.133 ± 12.716	<0.015*
TDA°	39.67 ± 14.490	23.13 ± 3.925	16.533 ± 12.878	<0.001*
CPA°	4.53 ± 10.295	12.47 ± 8.210	-7.933 ± 8.366	<0.002*

Mean pre, preoperative mean value of angle; mean post, postoperative mean value of angle; Diff, mean correction power of angle.
*Significant.

(4) The patient satisfaction rate was 100% (15 of 15 feet) in group 2 compared with 93% (14 of 15 feet) in group 1.
(5) This difference between the two groups was not statistically significant in such sample size (P=0.353).
(6) All cases (100%) demonstrated good tolerance to shoes in group 2 (15 of 15 feet), whereas 93% (14 of 15 feet) in group 2.
(7) This difference between the two groups was not statistically significant in such a sample size (P=0.353).
(8) Statistical analysis of complication rates (Table 7) showed that there was no statistically significant difference between the two groups in such a sample size (P=0.242).
(9) There is relatively higher undercorrection rate in the calcaneo stop group, with one case showing undercorrection of one component only of the deformity (i.e. forefoot abduction).
(10) In group 2, there was no undercorrection (Fig. 6).

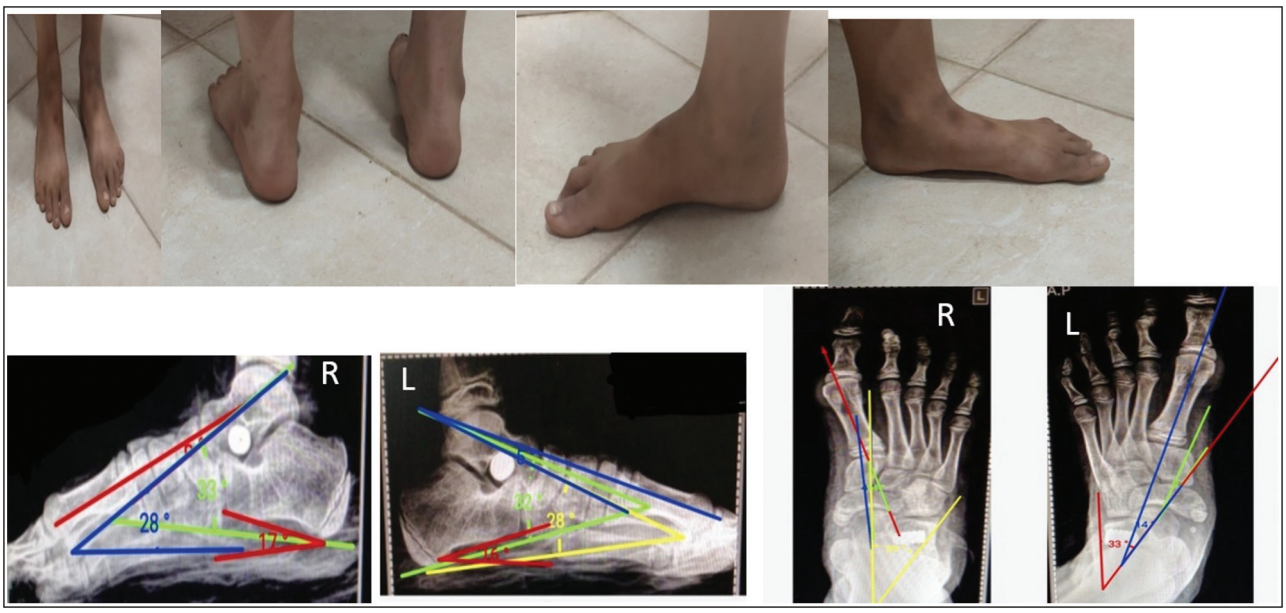
Table 7 Transient and persistent complications of both groups

Complications	Calcaneo stop	Endorthesis
Transient (<6 months)		
Pain	5	3
Temporary supination	2	0
Superficial wound infection	0	1
Persistent (≥6 months)		
Pain	2	1
Undercorrection	1 (one component-forefoot abduction)	0

Discussion

(1) The purpose of this study was to evaluate and compare the effectiveness of two different procedures (calcaneo stop and endorthesis) in the correction of idiopathic symptomatic flexible PPV in pediatric patients. To date, there has been no study comparing between calcaneo stop and endorthesis in idiopathic symptomatic flexible PPV in pediatric patients. Regarding the optimal age for surgical intervention for symptomatic cases, Evans [19] suggested that the ideal age group was between 8 and 12 years old, which is the optimal age for both subtalar arthroereisis and lateral column lengthening in the majority of the literature. Mosca [20] reported that the mean age at the time of surgery was 10 years (range, 4–16 years). Dogan *et al*. [21] mentioned that the mean age was 9 years (range, 4–13 years). In our study, the average age of our patients at the time of surgery was 9.90 years (range, 7–14 years) in group 1 and 9.70 years (range, 8–14 years) in group 2, which was near to the limits suggested by the previous studies. We found that the two treatments may affect the flatfoot complex differently; clinically (Table 4), we found that calcaneo stop was more powerful in correcting hindfoot valgus (was normalized in 80% of group 1 feet compared to 73.3% of group 2 feet); however, the difference was not statistically significant in such a sample size (P=0.493).
(2) Endorthesis was more powerful in correcting longitudinal arch (was normalized in 66.7% of group 2 feet compared with 53.3% of group 1

Figure 6



Postoperative radiographic and clinical photographs after endorthesis procedure.

feet); however, the difference was not statistically significant in such a sample size (P=0.252).

Regarding the radiological results, the difference between the two groups regarding the power of radiographic angle correction was not statistically significant for all angles (Table 8).

Few studies are available in the literature presenting the results of calcaneo stop or endorthesis, of which fewer studies are available as treatment options of idiopathic symptomatic FFF in pediatric. Chong *et al.* [22] (from 2010 to 2011) prospectively compared subtalar arthroereisis with lateral column calcaneal lengthening for the treatment of painful flatfeet. A total of 24 feet (mean age of patients 12.8 years) were treated. The mean follow-up period was 1 year. They studied five radiographic parameters and found that eight [all the angles in our study except AP TCA, and talar head coverage percentage (COVER%)] showed statistical significant differences between the satisfactory and unsatisfactory groups at the final revision with significant correlations (Table 9).

Yu *et al.* [23] reviewed the application progress of subtalar arthroereisis for the correction of pediatric flatfoot in children and analyzed the problems at present as well as to predict the trend of development in the field.

Domestic and abroad literature concerning the methods of subtalar arthroereisis applied in pediatric flatfoot in recent years was reviewed extensively and thoroughly analyzed.

Subtalar arthroereisis has proved to yield good results for correction of the flatfoot in children. In addition to the advantages of subtalar arthroereisis for pediatric flatfoot treatment (simple procedure, mature technology, and less complications), it allows further surgery if needed.

The authors concluded that subtalar arthroereisis is a simple and effective way to treat flatfoot in children; however, its biomechanics mechanism and managements to complication need to be explored further.

Metcalfe *et al.* [3] noted that pediatric FFF is a common deformity for which a small but significant number undergo corrective surgery.

Arthroereisis is a technique for treating FFF by means of inserting a prosthesis into the sinus tarsi. The procedure divides opinion in respect of both its effectiveness and safety.

A database search up until 2010 was used to find articles regarding arthroereisis in pediatric patients. These researchers summarized the findings of this study.

Table 8 Comparison between changes in radiographic angles between the two groups

Variables	Procedure		Diff	*P* value
	Calcaneo stop Mean 1	Endorthesis Mean 2		
TNCA°	22.67±15.472	20.533±11.470	2.133	0.671
AP T-1ST°	19.40±11.728	18.800±12.219	0.600	0.889
AP TCA°	12.67±6.651	16.533±8.626	-3.867	0.180
LAT T-1ST°	14.27±6.850	18.800±13.305	-4.533	0.251
LAT TCA°	12.27±8.916	9.133±12.716	3.133	0.441
TDA°	17.80±13.127	16.533±12.878	1.267	0.792
CPA°	-6.93±6.933	-7.933±8.366	1.000	0.724

Mean 1, mean correction (change) in calcaneo stop group; mean 2, mean correction (change) in endorthesis group; Diff, the difference in correction between the two groups.

Table 9 Comparison between change of the angles in our study (calcaneo stop group) and their corresponding angles of arthroereisis in Chong *et al.* [22] study

Study	Arthroereisis Chong *et al.* [22]					Calcaneo stop (our study)			Endorthesis (our study)			
Parameters	Mean pre	Mean post	Mean pre	Mean post	Diff	*P* value	Diff	*P* value	Mean pre	Mean post	Diff	*P* value
TNCA	31°	19.1°	32.13	11.60	20.533	<0.001	-11.9°	0.0001	32.60	9.93	22.67	<0.001
AP T-1ST	18.9°	8.3°	24.47	7.67	18.800	<0.001	-10.6°	0.0003	22.93	3.53	19.40	<0.001
LAT T-1ST	23.8°	12.3°	24.27	5.47	18.800	<0.001	-11.5°	0.001	18.67	4.40	14.27	<0.001
LAT TCA	52.9°	43.8°	42.60	33.47	9.133	<0.015	-9.1°	0.004	42.60	30.33	12.27	<0.001
CPA	13°	11.7°	4.53	12.47	-7.933	<0.002	-1.3°	0.01	3.74	10.40	-6.93	<0.002

A total of 76 studies were identified; eight of the nine radiographical parameters reported showed significant improvement following arthroereisis reflecting both increased static arch height and joint congruency. Calcaneal inclination angle demonstrated the least change with only small increases following arthroereisis.

Arthroereisis remains associated with a number of complications including sinus tarsi pain, device extrusion, and undercorrection. Complication rates range between 4.8 and 18.6% with unplanned removal rates between 7.1 and 19.3% across all device types.

The authors concluded that current evidence is limited to consecutive case series or ad hoc case reports. Limited evidence exists to suggest that devices may have a more complex mode of action than simple motion blocking or axis altering effects.

The interplay between osseous alignment and dynamic stability within the foot may contribute to the effectiveness of this procedure. They stated that although literature suggests patient satisfaction rates of between 79 and 100%, qualitative outcome data based on disease specific, validated outcome tools may improve current evidence and permit comparison of future study data.

Caravaggi *et al*. [24] stated that FFF is a common alteration of the foot diagnosed in the pediatric population causing pain and decreased quality of life. Surgical treatment via arthroereisis of the subtalar joint can be recommended when noninvasive options do not result in sufficient pain relief.

Although clinical outcome of subtalar joint arthroereisis is generally positive, no functional evaluation has thus far been reported following surgery. In a prospective study, these investigators evaluated the effects of two arthroereisis implants for the correction of bilateral FFF on foot and lower limb biomechanics during gait.

This trial entailed a total of 13 children affected by bilateral symptomatic FFF. Patients underwent bilateral subtalar joint arthroereisis during the same surgery using two types of poly-L-lactide bioabsorbable implants: an expanding endo-orthotic implant, and a calcaneo-stop screw.

Radiological parameters and gait analysis were performed preoperatively and at 1-year follow-up and compared with those from an age-matched normal-arched control population. Lower limb and multisegment foot kinematic analysis, along with electromyography of the main ankle flexor/extensor muscles, were performed during level walking at comfortable speed.

Paired nonparametric Wilcoxon signed-rank test was used to assess differences in radiological and kinematic parameters between preoperative and postoperative assessments. All radiological parameters and frontal-plane orientation of the rear-foot in double-leg standing were improved at 1-year follow-up in both implant groups (e.g. calcaneo-stop: preoperative $=15 \pm 7^{\circ}$; postoperative $=6 \pm 9^{\circ}$; $P<0.01$). The endo-orthotic implant group showed significantly lower pronation/supination at the ankle and midtarsal joint.

Activation of the tibialis anterior muscle was more physiological after surgery in both groups. The authors concluded that according to the present analysis, both implants appeared effective in restoring physiological alignment of the rear-foot; however, the endo-orthotic implant appeared more effective in restoring a more correct frontal-plane mobility of foot joints.

This was a small study (n=15) with short-term follow-up (1 year). These preliminary findings need to be validated by well-designed studies with larger sample size and long-term follow-up. Bernasconi *et al*. [25] noted that the role of SA for treating FFF in children is controversial. These investigators hypothesized that SA provided significant radiographic correction of low longitudinal arch and forefoot abduction in pediatric FFF and that midterm clinical outcomes were satisfactory and comparable to a normal population. They carried out a retrospective, comparative study of pediatric patients with symptomatic FFF who underwent SA between 2012 and 2015.

Multiple measurements on preoperative and latest follow-up radiographs were recorded by two observers and compared to evaluate for correction of the FFF. Intraobserver and interobserver reliability was also assessed. Ankle and hind-foot range of motion, AOFAS hind-foot score, and VAS-FA score were compared with controls without foot symptoms or deformity.

From 70 consecutive feet, 62 (31 patients) treated at 10.5 years of age were identified and compared with 48 controls (24 patients). The mean follow-up was 62 months. Intraobserver and interobserver reliability was excellent for all angles (range, 0.81–0.97).

Radiographic measurements demonstrated significant improvement after surgery ($P<0.001$); however, significance was not reached in TN coverage angle (P=0.49) and calcaneo-fifth metatarsal angle (P=0.53) on dorso-plantar view.

At latest follow-up, patients had less hind-foot inversion than controls (15.1° vs. 19.3°, *P*=0.03), lower AOFAS scores (94.1 vs. 99.6 points, *P*=0.01), due to pain (*P*=0.01), and alignment (*P*=0.006) subscores.

Using the VAS-FA score, patients were found to demonstrate higher pain at rest (*P*0.02–0.03) and during activity (*P*=0.009), and felt limited when standing on 1 leg (*P*0.01–0.03) and running (*P*=0.04).

No loss of correction was found after removal of the implant

The authors concluded that the findings of this study showed that SA corrected the low longitudinal arch in symptomatic pediatric FFF but did not correct forefoot abduction in relation to the hind-foot. Midterm assessment revealed SA provided satisfactory ankle and hind-foot range of motion, pain, and function levels, but limitations were witnessed compared with unaffected individuals. These researchers stated that this aspect should be considered when counseling patients and their parents or care givers to allow for realistic expectations. Level of evidence=III.

Vogt *et al*. [26] stated that STA is a minimally invasive and reversible surgery to correct symptomatic FFF in children. Various techniques have been described either applying expandable sinus tarsi implants or lateral calcaneus stop screws.

Studies comparing the outcome of STA with different devices are rare. In a retrospective, single-center, cohort study, these researchers analyzed the results of STA using three different implants. A total of 113 STAs were performed in 73 consecutive patients (28 females). The mean age at surgery was 10.8 years (range, 5–16). The mean follow-up was 29.0 months (range, 1–111).

In 21 feet, the nonabsorbable Kalix endorthesis and in 56 feet the absorbable Giannini endorthesis were applied.

Subtalar extra-articular screw arthroereisis (SESA) was performed in 36 feet. Clinical, radiographic, and pedobarographic parameters were analyzed. No intraoperative complications were observed.

All three procedures achieved comparable improvements of the clinical, radiographic, and pedobarographic parameters.

The mean foot function index improved from 36.4 (range, of 12–63) to 22.8 (range, 2–55).

The mean preoperative calcaneal inclination angle and the lateral talocalcaneal angle improved from 9.5° (range, of 0–22°) and 42.3° (range, 21–62°) to 12.8° (range, 026°) and 37.6° (range, 15–56°), respectively. Pedobarographically determined values of the arch index, the medial mid-foot contact area, and the medial forefoot peak pressure decreased. In contrast to SESA (1/36, 3%), a higher incidence of implant-related complications was observed using Kalix (6/21, 29%) and Giannini (10/56, 8%) sinus tarsi implants. Peroneal muscle contractures only occurred in the SESA group (4/36, 11%). Premature removal due to treatment-related complications was needed in 6/21 Kalix implants (29%), 4/56 Giannini implants (7%), and 4/36 SESA implants (11%).

Implant choice for treatment of painful FFF in children with STA appeared to play a subordinate role.

Clinical, radiographic, and pedobarographic outcomes were comparable between the applied implants. Surgeons and patients should be aware of the different spectrum of implant-related complications. Treatment can be reliably monitored by radiation-free pedobarography providing dynamic information about the deformity.

The authors stated that this study had several drawbacks as a consequence of its retrospective character and is biased by different cohort sizes, availability of the implants, and uneven distribution of the etiologies. Patients were only included until 2013, as owing to logistic reason, pedobarographic analysis was inconsistently available after 2013.

STA implants were used consecutively due to their availability and not during the same period. Time-related parameters such as the surgeon's expertise, evolution of implants, and improved outcome measures with time might limit comparability of the studied cohorts. The statistical findings of this study should carefully be interpreted.

We encourage readers to focus more on the clinical, radiographic, and pedobarographic outcomes, rather than statistical comparisons and *P* values.

The fact that some patients were treated bilaterally and others unilaterally can limit comparability. Some statistical findings might not be applicable to every patient group. Most patients were immature at the time of implant removal or last follow-up, and the study lacks long-term observation after treatment focusing on maintenance of the correction and occurrence of recurrent deformity. Furthermore, this study does not provide a control group to compare the outcome with the natural development of pediatric foot shape over

time. Prospective randomized trials are needed to compare the benefits and disadvantages of the available implants with a long-term follow-up.

Conclusion

There was a statistically significant improvement in both primary and secondary outcome parameters after both procedures in comparison with the preoperative parameters. No statistically significant differences were observed between the two groups regarding the outcomes of both procedures. Therefore, both procedures are valid options for the surgical management of idiopathic symptomatic flatfoot in pediatric patients. However, further investigation and long-term outcome studies are warranted to demonstrate the efficacy and safety of arthroereisis.

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Conflicts of interest

There are no conflicts of interest.

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