Short and mid-term results of arthroereisis in the management of flexible pesplanovalgus in adolescents

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Received: 17-Jun-2023
Revised: 16-Jul-2023
Accepted: 20-Jul-2023
Published: 08-Mar-2025

The Egyptian Orthopaedic Journal 2024, 59:719–726

Introduction
Flexible flatfoot is a common deformity in children and adults.Various conservative and surgical procedures have been defined in the treatment of symptomatic flexible flatfoot.Surgeons have been using subtalar joint arthroereisis implant techniques for over 35 years and have routinely reported good short-term results. However, on a midterm to long-term studies there is a variation in the results.
Patients and methods
This is a prospective case series study to evaluate the effectiveness and complications of arthroereisis in the management of flexible pesplanovalgus in adolescents.This study included 50 feet with symptomatic flexible flatfoot all of them had arthroereisis implant insertion with or without soft tissue procedures as indicated.
Result
As regard clinical evaluation there is significant correction of the heel valgus angle, AOFAS score and FAAM score.
As regard radiological evaluation there is significant correction of the AP Talus 1st metatarsal angle, AP Talonavicular coverage angle, Lateral talus 1st metatarsal angle, Talocalcaneal angle and calcaneal pitch angle.

Keywords:
Pesplanovalgus, flatfeet, foot deformity, valgus heel

Egypt Orthop J 2024, 59:719–726

1110-1148

Introduction

Flexible flatfoot is a common deformity in children and adults. It is characterized by medial rotation and plantar flexion of the talus, eversion of the calcaneus, collapsed medial arch, and abduction of the forefoot. In general, infants are born with a flexible flatfoot, with the arch of the foot typically developing during the first decade of life. Most flexible flatfoot cases resolve spontaneously or remain asymptomatic, whereas symptomatic and pathological conditions require treatment [1].

Various conservative and surgical procedures have been defined in the treatment of symptomatic flexible flatfoot. Conservative interventions include shoe modification, orthoses, physical therapy, and exercise modifications. However the recent literature reviews on the effect of pediatric foot orthoses found very limited evidence on the effectiveness of non-surgical interventions in children with flexible flat foot [2].

The most difficult aspect regarding treatment of the pediatric flatfoot is understanding who needs surgery, when it is necessary, and what procedure to be done. A thorough history, clinical examination, and imaging should be performed to guide the surgeon through an often complex treatment pathway. Surgical technique can be divided into two main categories: arthroereisis (subtalar implant) and Soft tissue and bony correction (corrective osteotomies) [3].

Some patients may present with mild pain but severe deformity, while other may show mild deformity with severe pain [3].

Subtalar arthroereisis is a surgical procedure that involves placing an implant that has the appearance of a threaded cylinder into the sinus tarsi between the talus and calcaneus to stabilize the foot. It may be performed on both children and adults for adolescent and adult onset pes planovalgus deformity [4].

The goal of the subtalar joint arthroereisis is to reduce the pronation range of motion of the subtalar joint (STJ) in order to create a change in the alignment

and function of the foot and lower extremity during weight-bearing activities [5].

Surgeons have been using subtalar joint arthroereisis implant techniques for over 35 years and have routinely reported good short-term results. However, on a mid-term to long-term studies there is a variation in the results [5].

Further scientific research and more long-term studies of arthroereisis implant patients will be necessary to better clarify both the positive and negative alterations in foot and lower extremity biomechanics that may occur after this surgical procedure [6].

So this study was designed to evaluate the effectiveness, advantages, disadvantages and postoperative complications of arthroereisis procedure in the management of flexible pes planovalgus in adolescents.

Patients and methods

This is a prospective case series study that was conducted between August 2016 and May 2023.

The inclusion criteria were Idiopathic flexible flatfoot deformity, symptomatic patients only after failure of conservative measures and age between 10–14 years' old.

While the Exclusion criteria were Severe talonavicular uncoverage angle (>40), Neurogenic cases (cerebral palsy patient) and Patients with generalized ligamentous laxity.

Patients presented to our orthopedic outpatient clinic with symptomatic flexible Pes planovalgus after failure of conservative measures were included in the study.

All patients were screened for suitability by detailed clinical assessment of their history and physical examination as well as radiological investigations and those who met the operative criteria were included in this study.

Ethical committee approval was obtained, and informed consent was taken from the parents. No fund was obtained, and no conflict of interest existed.

This study included 50 feet in 30 patients with symptomatic flexible flatfoot (20 bilateral, 10 unilateral).

Xtalus 'Episcan' subtalar endorthesis implant is used.

Patients with bilateral affection were operated upon simultaneously.

The incision is made in the 'soft spot' just proximal to the anterior process of the calcaneus. Avoid injury of the superficial branch of the peroneal nerve

Bluntly the subcutaneous tissues dissected into the tarsal canal with a small hemostat to create a pathway for the Guidewire.

The Guidewire inserted through the tarsal canal. This wire passes about 15° off the perpendicular to the sagittal plane going from anterolateral to posteromedial. The surgeon should aim for the sustentaculum tali medially. The Guidewire will tent the skin medially and a 1–3 mm incision can be made here to permit clamping of the protruding wire. The wire will exit below the posterior tibial tendon.

The trial sizer inserted over the Guidewire. Different trial sizers inserted. Initial assessment should check for eversion of the calcaneus. If too much eversion is present, the diameter of the trial sizer increased and reassess. On AP intraoperative image. Implant/sizer should not be medial to the midline of the talar neck. The lateral edge of the implant should be at or just medial to the lateral side of the talus.

The implant inserted using the driver. It is suggested to maintain the foot in an everted position while disengaging the screw driver. Final placement confirmed by fluoroscopy check.

Soft tissue procedures were added to both groups if indicated, mainly gastrocnemius recession and accessory navicular excision.

Patients splinted for three weeks then started weight-bearing and physiotherapy.

Postoperative clinical evaluation

Hind foot valgus position calculated at 6 weeks, 3months, 6 months and every 6 months.

Patient satisfaction, AOFAS score and FAAM score calculated at 6 months, one year and two years.

Postoperative radiological evaluation

Weight-bearing ankle and foot radiographs (AP and lateral) were taken immediately postoperative, at 3 weeks, 6 weeks, 3 months and at 6 months then every 6 months.

They were evaluated for the lateral talocalcaneal angle, AP talus 1st metatarsal angle, lateral talus 1st metatarsal

angle, talonavicular coverage angle and calcaneal pitch angle.

Statistical analysis

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean±standard deviation (SD).

The following tests were done

(1) Independent-samples t-test of significance, Paired sample t-test of significance, Wilcoxon Signed-Rank Sum test, χ^2 test of significance and Fisher's exact test all these tests was done to obtain the results.
(2) The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the *P* value was considered significant as the following:
(3) Probability (*P* value)
    (a) *P* value ≤0.05 was considered significant.
    (b) *P* value <0.001 was considered as highly significant.

P value >0.05 was considered insignificant.

Results

The minimum follow-up duration for the patients was 12 months and average of 34.01 ± 16.14 (range 12–60).

As regard the patients age the mean±SD was 11.90 ± 2.01. The sex also was 14 females (46%) and 16 males (54%).

As regard to associated procedures: 8 feet (16.0%) had accessory navicular excision with reattachment of tibialis posterior tendon by transosseous sutures; 31 feet (62.0%) had gastrocnemius recession; 4 feet (8.0%) had both gastrocnemius recession and accessory navicular excisin; 7 feet (14.0%) had no associated procedures.

The patients Preoperative mean **heel valgus angle** was 14.05 ± 3.79 compared to 2.75 ± 2.62 postoperative, there was highly statistically significant reduction in Postoperative mean compared to Preoperative with (*P* value <0.001 highly Significant), this indicates improvement postoperative.

Additionally, the patients Preoperative mean **AOFAS score** was 73.80 ± 7.46 compared to 89.25 ± 8.34 postoperative, there was highly statistically significant increase in Postoperative mean compared to Preoperative with (*P* value <0.001 highly Significant), this indicates improvement postoperative.

Furthermore, the patients Preoperative mean **FAAM score** was 73.75 ± 6.49 compared to 91.08 ± 6.51 postoperative, there was highly statistically significant increase in Postoperative mean compared to Preoperative with (*P* value <0.001 highly Significant), this indicates improvement postoperative.

The clinical data measured at 6 months, 1 year and every year after and did not show change in the results.

NB:the patient is standing on a hard floor in the postoperative photos (Figs 1–4) but on a blue linen just for better quality photos.

Figure 1

Clinical photo showing preop. (A) and postop. (B) hindfoot valgus lt side Heel valgus angle corrected from 15° to 0°.

Figure 2

Clinical photo showing preop. (A) and postop. (B) hindfoot valgus Rt side Heel valgus angle corrected from 18° to 0°.

Figure 3

Clinical photo showing preop. (A) and postop. (B) medial arch of the Lt foot.

Figure 4

Clinical photo showing preop. (A) and postop. (B) medial arch of the Rt foot.

Radiological data: The patients preoperative mean **LAT talus 1st met angle** was 19.95 ± 11.10 compared to 3.45 ± 2.06 postoperative, there was highly statistically significant reduction in Postoperative mean compared to Preoperative with (*P*-value <0.001 highly Significant), this indicates improvement postoperative.

Additionally, the patients' preoperative mean **LAT talocalcaneal angle** was 43.55 ± 6.19 compared to 32.65 ± 5.05 postoperative, there was highly statistically significant reduction in Postoperative mean compared to Preoperative with (*P*-value <0.001 highly Significant), this indicates improvement postoperative.

Furthermore, the patients' preoperative mean **calcaneal pitch angle** was 9.75 ± 4.95 compared to 15.75 ± 4.64 postoperative, there was highly statistically significant reduction in Postoperative mean compared to Preoperative with (*P* value <0.001 highly Significant), this indicates improvement postoperative (Figs 5 and 6).

As well as, the patients preoperative mean **AP talus 1st metatarsal angle** was 17.85 ± 5.80 degrees compared to 6.72 ± 5.17 degrees postoperative, there was highly statistically significant reduction in Postoperative mean compared to Preoperative with (*P* value <0.001 highly Significant), this indicates improvement postoperative.

As notices that, the patients preoperative mean **AP talonavicular coverage** was 18.50 ± 8.79 compared to 6.95 ± 3.77 postoperative, there was highly statistically significant reduction in postoperative mean compared to preoperative with (*P* value <0.001 highly significant), this indicates improvement postoperative.

The Radiological data measured at 6 months, 1year and every year after and didn't show change in the results (Figs 7 and 8).

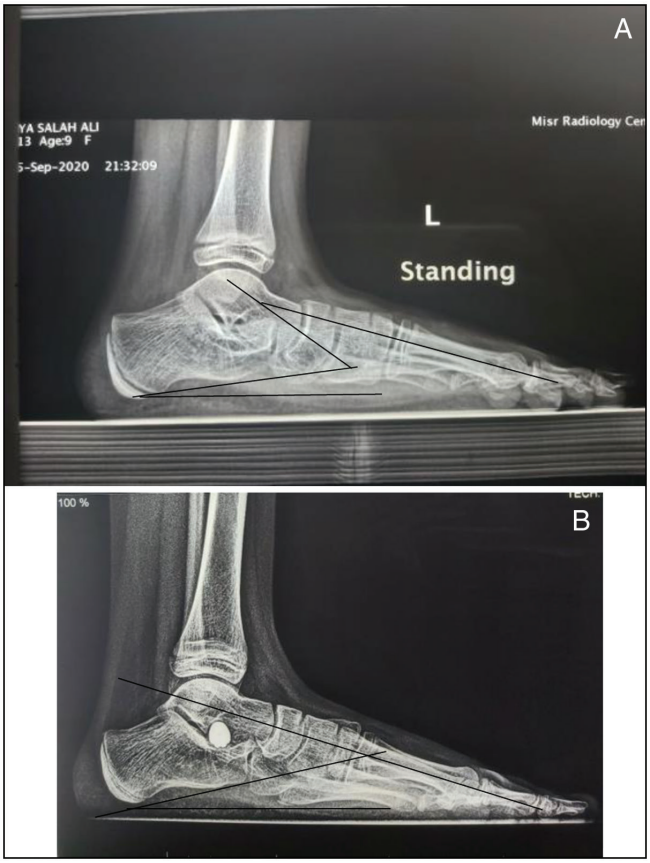
Reduction of the AP talo-1st MTS from 12° preoperative (A) to 0° postoperative (B).

Reduction of the AP talonavicular coverage angle from 30° preoperative (A) to 16° postoperative(B).

Discussion

There are numerous studies that have provided the evidence basis, safety and effectiveness of this minimally invasive joint sparing procedure. There is evidence of radiographic normalization of osseous realignment, restoration of navicular height/position, maintenance of arch height, restoration of joint congruity, rebalancing of subtalar joint forces, decreased strain to the plantar fascia, posterior tibial nerve, and tendon, improved function and pain scores, improved

Figure 5



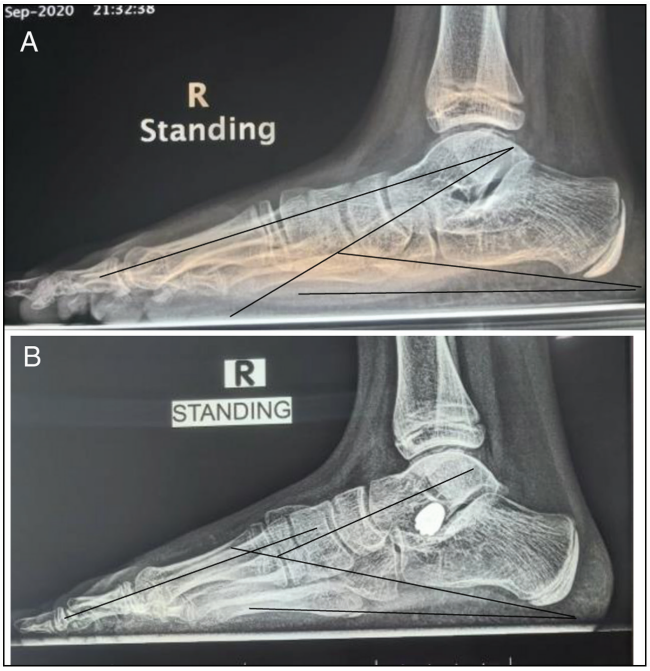
Radiograph showing pre op(A) and post op (B) talocalcaneal angle, talus 1st MT angle and calcaneal pitch angle lt side Reduction of the lat.-TCA from 45° preoperative (A) to 30° postoperative (B) indicates improvement of the hindfoot valgus. Reduction of the Lat. Talo-1st MTS from 20° preoperative (A) to 0° postoperative (B) indicates improvement of the foot medial longitudinal arch. Increase of the calcaneal pitch angle from 7° preoperative (A) to 14° postoperative (B) indicates improvement of the foot medial longitudinal arch.

ankle joint alignment, return to sports activity, and improved emotional status. Pediatric patients report a high degrees of satisfaction, and their quality of life was improved and not compromised by the procedure [7].

In 2019, a study by Panos Megremis *et al.*, included 28 feet in 14 children who underwent subtalar arthroereisis in association with percutaneous triple-hemi section Achilles tendon lengthening [7].

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 the talonavicular joint lateral subluxation is present, 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.

Figure 6



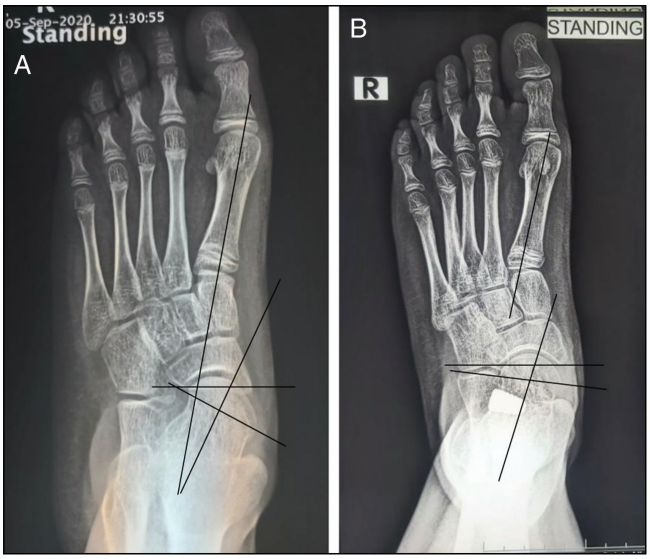
Radiograph showing pre op (A) and post op (B) talocalcaneal angle, talus 1st MT angle and calcaneal pitch angle right side. Reduction of the lat.-TCA from 40˚ preoperative (A) to 34˚ postoperative (B). Reduction of the Lat. Talo-1st MTS from 12˚ preoperative (A) to 2˚ postoperative (B). Increase of the calcaneal pitch angle from 6˚ preoperative (A) to 11˚ postoperative (B).

Figure 7

Radiograph showing pre op (A) and post op (B) talus 1st metatarsal angle and talonavicular coverage angle lt side Reduction of the AP talo-1st MTS from 10˚ preoperative (A) to 0˚ postoperative (B) indicates improvement of the forefoot abduction. Reduction of the AP talonavicular coverage angle from 13˚ preoperative (A) to 1˚ postoperative (B) indicates improvement of the forefoot abduction.

The minimum follow-up duration was 19 months, with a mean follow-up duration of 35.14 ± 9.82 (range 19 to 60) months.

Figure 8



Radiograph showing pre op (A) and post op (B) talus 1st metatarsal angle and talonavicular coverage angle rt side.

For estimation of the efficacy of the surgical procedure, the American Orthopaedic Foot and Ankle Society (AOFAS) rating scale was used preoperatively and postoperatively in all patients. The mean preoperative AOFAS 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. After arthroereisis surgical treatment, all AOFAS scores and all foot angles improved significantly, except the calcaneal inclination angle which improved slightly [7].

In 2011 in a systematic review by Metcalfe *et al*., regarding arthroereisis there was many studies reporting improvements in radiological outcomes and high satisfaction rates among patients. They acknowledge there is a lack of evidence for the indications of arthroereisis and studies they included lacked standardization and did not use disease-specific validated outcome tools [6].

A review by Tan *et al*. in 2020 also investigated the use of arthroereisis in pediatric pes planus. They concluded that arthroereisis is effective in reducing symptoms and deformity. Their review could be criticized for including patients aged up to 21 years and also studies treating rigid pes planus [8].

In 2021, a database search for outcomes of arthroereisis by Smith C *et al*., for the treatment of symptomatic pediatric flexible pes planus, 24 articles were included, with a total of 2550 feet operated on. The 24 studies consist of 5 prospective case series, 13 retrospective case series, 3 prospective non-randomized comparative studies and 3 retrospective non-randomized comparative studies [9].

Postoperative patient-reported outcome measures recorded marked improvement.

Satisfaction was reported as excellent in 79.9%, and poor in 5.3%.

All radiological measurements demonstrated improvement towards the normal range following arthroereisis, as did hind foot valgus, supination, dorsiflexion. Complications were reported in 7.1% of cases, with a reoperation rate of 3.1% [9].

In our study our clinical and radiological data were comparable to the previous results with a larger number of patients.

And about the complications we had 2 feet with sinus tarsi pain, 1 foot had recurrence, 2 feet with under-correction and 2 feet with superficial wound dehiscence.

There are 4 feet (2 patients) that showed minimal extrusion postoperative, and this didn't affect the correction and the clinical and radiological measures corrected and didn't had recurrence during follow-up (Figs 9 and 10).

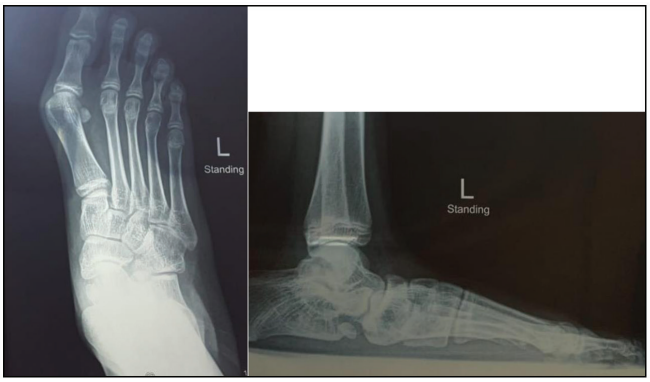
Indeed, abduction correction after arthroereisis remains debated within literature as well. On a side, some studies do report substantial improvements in talonavicular coverage. These studies achieved abduction correction without Achilles procedures but they document the application of a below knee cast after surgery, therefore raising the possibility that postoperative immobilisation in a corrected position might improve the talonavicular angle [10–12].

On the other side, a review by Suh *et al*. in 2019 suggested that STA should be indicated only in FFF with mild abduction and that LCL should be preferred to achieve better correction in severe talonavicular uncoverage (>40 to 50%) [13].

Unfortunately, the heterogeneity of studies included and the absence of direct comparative cohorts make difficult to establish if the morphological correction depends on the subtalar implant or on any additional procedure performed to achieve correction [13].

In our study we preferred to exclude patients with severe talonavicular uncoverage (angle >40°) to be out of this debate and to obtain accurate data about the

Figure 9



Preoperative radiograph of female patient 12 years old.

Figure 10

Last follow-up of the same patient with extrusion and without recurrence of the deformity.

effectiveness of both methods in a certain group of patients.

Another entity is the improvement of calcaneal pitch angle after arthroereisis, several studies did not report improvement of the calcaneal pitch angle after arthroereisis. They assume that this may be due to the site of correction is at the level of the subtalar joint [6,14,15].

The calcaneal inclination angle improved significantly in our study in the arthroereisis group.

The correction of the calcaneal inclination angle may be due to blocking calcaneal eversion though preventing the talus from plantar collapse that leads to 3D correction of the pes planovalgus.

Removal of arthroereisis implant is a very important issue that carry a lot of debate. Incidence of sinus tarsi pain has been reported as high as 46% in the adult population that may lead to removal [16].

There is a great variation of unplanned removal rate due to sinus tarsi pain in children, they differ in literature from 0% [17] and up to 39% with certain types of implant [16].

In our study we have only one patient with sinus tarsi pain and didn't require removal as the pain is tolerated and has an on and off pattern.

In literature there is a lack of evidence about planned removal of the implant or should it be removed as the patient is near maturity or not, and if we can remove it what is the minimum time required before removal.

older studies had suggested that an implant should be maintained in place for at least two years to allow adequate bone and soft-tissue adaptation [18,19].

However, this is not a settled fact and further studies is still required regarding planned implant removal. In our study we didn't do removal for any case.

Limitations and recommendations

The follow-up is relatively short and Longer follow-up is recommended to detect possibility of recurrence.

Arthroereisis should be evaluated in severe talonavicular uncoverage in a separate study.

We noticed long rehabilitation time in the patients (about 4 months) but it's not accurately calculated and this also may be related to bilaterality of most patients that requires more rehabilitation time, Time of rehabilitation and return to normal activity and sports should be considered in coming studies.

Conclusion

Arthroereisis has several advantage as a technique in management of flexible adolescent pesplanovalgus deformity.

These advantages can be summarized as it is a simple procedure, no bone graft needed, spares the chance

for later osteotomies if needed, minimal opening with minimal wound complications, can do both sides together, allows for early weight-bearing and has a good corrective power.

While the disadvantages from the procedure can be summarized as it has a limited age of application and has specific complications such as sinus tarsi pain and implant extrusion.

Acknowledgements
Nil.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors declare no financial or non-financial conflicts of interest related to this study.

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