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Arthroereisis of the subtalar joint in the management of pediatric flexible flatfoot: A retrospective clinical study

Çağrı Neyişci, Yusuf Erdem, Ahmet Burak Bilekli

Gulhane Training and Research Hospital, Department of Orthopedics and Traumatology, Ankara, 06010, Turkey

ORCID ID of the author(s)
ÇN: 0000-0001-8481-7808
YE: 0000-0002-8685-2356
ABB: 0000-0002-6294-4838

Corresponding Author
Çağrı Neyişci
Department of Orthopedics and Traumatology, Gülhane Training and Research Hospital, Ankara, Turkey
E-mail: cagri_neyis@yahoo.com
drcagrineyisci@gmail.com

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Ethics committee approval was received for this study from Gülhane Scientific Research Ethics Committee (2021/65).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

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Abstract

Background/Aim: Management of flatfoot is still a challenge for orthopedic surgeons because it is a common and physiological process that usually requires observation and follow-up due to its asymptomatic nature in the pediatric population. The aim of this study was to investigate the radiological and pedobarographic results of symptomatic flexible flatfoot in pediatric patients who were treated by simultaneous gastrocnemius lengthening and arthroereisis of the subtalar joint.

Methods: This retrospective cohort study included 20 feet of 10 children (5 males, 5 females; mean age: 11.4 years; age range 9-14 years) who underwent simultaneous gastrocnemius lengthening and subtalar joint arthroereisis procedure for bilateral symptomatic flatfoot. The mean follow-up period was 24 months (range 11-32). All arthroereisis procedures were performed using a cannulated arthroereisis titanium implant. To assess the radiological results, calcaneal pitch angle and Meary's talus-first metatarsal angle on radiographs were measured preoperatively and at the final follow-up. Pedobarographic assessment was based on plantar heel and forefoot pressures preoperatively and at the final follow-up.

Results: The mean calcaneal pitch angle increased from 8° (0.93°) preoperatively to 16.5° (1.14°) postoperatively (P<0.001), while the mean Meary's talus-first metatarsal angle decreased from 7.5° (1.14°) preoperatively to 0.5° (0.51)° postoperatively (P<0.001). The mean heel peak pressure and forefoot peak pressure increased from 11.5 (1.14) N/cm^2 and 10.5 (1.14) N/cm^2 preoperatively to 17.5 (1.14) N/cm^2 and 15.5 (1.14) N/cm^2 postoperatively, respectively (P<0.001 for both variables). In addition, the pedobarographic assessment revealed that medially increased center of pressure moved to laterally increased center of pressure in all feet with an improvement in terms of forefoot and heel pressures. None of the patients experienced major intraoperative or postoperative complications.

Conclusion: Simultaneous gastrocnemius lengthening and arthroereisis of the subtalar joint seems an effective and safe surgical option for symptomatic flexible flatfoot in pediatric patients.

Keywords: Arthroereisis, Flatfoot, Gastrocnemius lengthening, Pediatric, Subtalar joint

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Introduction

Management of flatfoot is still a challenge for orthopedic surgeons because it is a common and generally physiological process that usually requires observation and follow-up due to its asymptomatic nature in the pediatric population [1]. Flexible flatfoot (FFF) is the most common form and the major abnormal biomechanical changes include valgus malalignment of the calcaneus, plantar deviation of the talus, and medial longitudinal arch collapse occurring during weight-bearing [1-3]. However, in symptomatic cases, this process can lead to subjective symptoms such as foot and ankle pain with postural difficulties [1]. Furthermore, additional equinus pathology (isolated gastrocnemius or gastro-soleus tightness) combined with FFF may aggregate pain along the medial side of the foot, heel, calf, knee, or low back during gait phases and make daily activities difficult, which sometimes extends to walking disability in children [2].

The main management of FFF requires physical and behavioral therapies, but surgical management is common [3-5]. Although there is still a controversy on the surgical indications and treatment modalities, surgical intervention is recommended when the child is complaining of excessive foot pain after 8 years of age [3]. The diagnosis is also based on parental warnings about child's unwillingness to walk or take part in athletic activities because of foot pain [4, 5]. Surgical management of symptomatic FFF includes diverse options: Soft tissue procedures (posterior tibial tendon transposition, Achilles/gastrocnemius lengthening, spring ligament repair), osteotomy and bony procedures (medializing calcaneal osteotomies, lateral column lengthening osteotomies), arthrodesis, and arthroereisis [5, 6]. The main goal of these procedures is to restore proper alignment between talus and calcaneus, and better results are obtained with osteotomies, bony procedures, and arthroereisis than with soft tissue procedures [7].

With increasing interest in foot and ankle sub-specialty and minimally invasive procedures, arthroereisis has become popular and widely accepted. However, the necessity of implant removal is still a negative aspect of the procedure, and most current studies focus on overcoming this problem by developing new bio-absorbable implants and evaluating their effects on correction [6, 8, 9]. There are few comparative studies investigating the biomechanical effects of this procedure on foot plantar pressures [10, 11].

The aim of this study is to investigate the alterations in foot biomechanics and plantar pressures utilizing pedobarographic and radiographic measurements in pediatric population who have undergone simultaneous gastrocnemius lengthening and arthroereisis procedure to treat symptomatic flatfoot with a tight heel cord.

Materials and methods

This retrospective study included 20 feet of 10 children (5 males, 5 females) who underwent bilateral gastrocnemius lengthening and simultaneous arthroereisis procedure for symptomatic flat feet between August 2016 and December 2018. Children between 9 and 14 years of age with idiopathic, flexible, symptomatic FFF (painful feet during standing and walking), and gastrocnemius/gastrosoleus tightness (positive Silverskiöld test) who had not responded to adaptive footwear, orthotics, or physiotherapy were included to our study. All patients were discharged on day 1 after operation with a short leg soft cast. Casts were removed 6 weeks after the operation, and the patients were encouraged to engage in full weight-bearing activities, as tolerated.

Exclusion criteria included post-traumatic, neurological or neuromuscular disorders, presence of joint hyperlaxity, foot synostosis, and clubfoot sequelae. Study protocol was approved by Gülhane Scientific Research Ethics Committee (2021/65) and conducted in accordance with the principles of the Declaration of Helsinki.

Physical examination

The diagnosis was based on clinical history and physical examination and documented by radiographs and pedobarographs. All patients were carefully examined preoperatively and at follow-up visits postoperatively by the same surgeon. Clinical diagnosis was based on increased hindfoot valgus position at rest and during tip-toe standing test. Postoperative clinical assessment also included the observations of parents regarding activities (physical domain assessing general activity limitations, assessing school and play participation restrictions, emotional domain assessing to what extent a child is bothered about their foot or ankle because of the appearance or the way people treat them, and wanting or not wanting to wear any shoes) of the children. Since clinical evaluation was not considered effective, scoring was not performed, and it was evaluated only if there was pain in daily and sports activities.

Radiographic assessment

The radiographic assessment included weight-bearing anteroposterior and lateral radiographs of the feet preoperatively and postoperatively at 6 weeks, 3 months, 6 months, 1 year, and 2 years. On radiographs, Meary's talar-first metatarsal angle and calcaneal pitch angle were measured (Figure 1). Additional computed tomography or magnetic resonance imaging studies were performed in patients when the aforementioned exclusion criteria were suspected.

Pedobarographic measurement

The pedobarographic assessment included plantar heel and forefoot (2-5 metatarsophalangeal joints and phalanges) pressures preoperatively and postoperatively at 6 weeks, 3 months, 6 months, 1 year, and 2 years. Footprint enlargement ratio (degree of plantar collapse) was evaluated using Viladot's classification [12] (Figure 2, 3).

Two masks of plantar foot pressures including heel and forefoot peak pressures were analyzed with the pedobarograph (footscan7®, RSscan International NV, Olen, Belgium) and were recorded as static and dynamic pressure data (Figure 4). Dynamic measurements were performed while the child was walking at natural speed.

Figure 1: a-f: (a) Preoperative, (b) anteroposterior, and (c) weight-bearing lateral radiographs of the flatfoot of a 10-year-old boy. Calcaneal pitch angle and Meary's angle were improved (d) postoperative, (e) anteroposterior, and (f) weight-bearing lateral radiographs of the foot after surgical correction

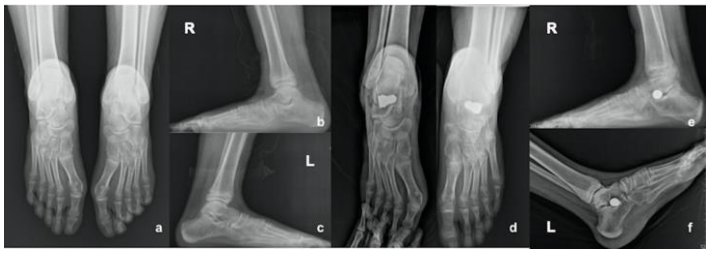


Figure 2: Footprint enlargement ratio according to Viladot [12]

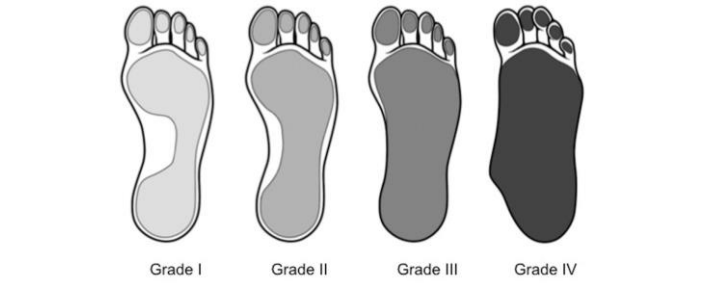
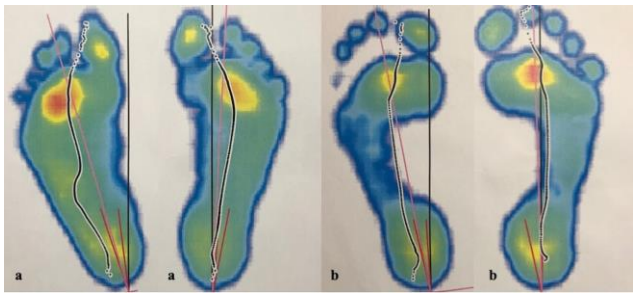


Figure 3: a, b. (a) Preoperative and (b) postoperative images of foot of a 10-year-old girl

Figure 4: a, b. (a) Preoperatively printed out and (b) postoperative static and dynamic pedobarographic measurements of 12-year-old girl with symptomatic flatfoot. Loading of plantar foot shifted laterally after surgery



Surgical technique

All children were placed supine on the operating table under general anesthesia. A tourniquet was applied on the thigh for a bloodless and adequately exposed surgical field for the gastrocnemius lengthening procedure. The foot and the leg were prepared in usual sterile fashion, and local anesthetic was applied to the incision sites for postoperative pain control. After inflation of the tourniquet, a longitudinal 6-7 cm incision medial to the midline was performed at the middle of the calf. After subcutaneous dissection, Z-shaped incision at the aponeurosis of the gastrocnemius muscle was made. With controlled passive dorsiflexion of the foot, elongation of the gastrocnemius was obtained. After that, a 2-cm oblique skin incision was made over the tarsal sinus approximately 1-1.5 cm distal to the tip of the lateral malleolus. Blunt dissection to the location of the tarsal sinus was carried out, and the soft tissues within were transected to create a soft tissue pocket for the insertion of the guide wire and trial sizer. Inadequate soft tissue transection compromises proper placement as well as the size of trials. The guide wire in the tarsal sinus canal should be in the configuration of distal-lateral to proximal-medial (Figure 5). In-line cannulated trial sizers from small to large were inserted into the canal over the guide wire, and proper size was selected by evaluating talotarsal mechanism until reaching the optimal hindfoot valgus which was considered less than 5°. After fluoroscopic assessment, a proper size titanium cone-shaped implant was placed into the canal, and plain radiographs were obtained to evaluate the position of the implant (Figure 6). After wound irrigation, hemostasis, closure, and dressing, a short leg soft cast was applied with the ankle in neutral position.

Figure 5: a-c. (a) Anteroposterior and lateral views of the guide wire and screw placement into the sinus tarsi in direction of distal-lateral to proximal-medial, (b) Neutral position of the heel after proper size implantation of subtalar correction screw (not varus/valgus), and (c) Intraoperative fluoroscopic images of correct placement of guide wire and screw

Figure 6: Cannulated arthroereisis titanium implant

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences for Mac version 23.0 software (IBM SPSS Corp.; Armonk, NY, USA). Descriptive data were expressed in mean (SD), number, and frequency. Paired samples t test was used to compare preoperative and postoperative calcaneal pitch angle, Meary's angle, heel peak pressure, and forefoot peak pressures. The interim analysis was performed by an independent statistician blinded for the treatment allocation. A *P*-value of less than 0.05 was considered statistically significant.

Results

Among 10 patients (20 feet), there were 5 (50%) females and 5 (50%) males with a mean age of 11.4 (1.46) years. The mean follow-up period was 24 (range: 11-32 months) months. Applied implant diameters were between 7-10 mm. Patients' demographic data, radiological, and pedobarographic results are presented in Table 1. The mean preoperative calcaneal pitch angle of 8° (0.93°) increased to 16.5° (1.14°) postoperatively ($P<0.001$). In contrast, the mean preoperative Meary's angle of 7.5° (1.14°) decreased to 0.5° (0.51°) postoperatively ($P<0.001$).

The mean preoperative heel peak pressure of 11.5 (1.14) N/cm^2 increased to 17.5 (1.14) N/cm^2 postoperatively, and the preoperative forefoot peak pressure of 10.5 (1.14) N/cm^2 increased to 15.5 (1.14) N/cm^2 postoperatively ($P<0.001$ for both) (Table 2).

Table 1: Patients' demographic data, radiologic, and pedobarographic results

No	Gender (female/ male)	Age (year)	Screw diameter (mm)	Calcaneal pitch angle (degree)				Meary's angle (degree)				Heel peak pressure (N/cm^2)				Fore foot peak pressure (N/cm^2)			
				Right		Left		Right		Left		Right		Left		Right		Left	
				PO	PT	PO	PT	PO	PT	PO	PT	PO	PT	PO	PT	PO	PT	PO	PT
1	F	11	9	7	15	8	15	6	0	9	1	10	16	13	19	9	14	12	17
2	M	10	8	8	16	7	17	8	1	7	0	12	19	11	16	11	17	10	14
3	M	9	10	8	18	8	17	9	1	6	0	13	18	10	17	9	15	11	16
4	M	13	7	9	17	7	15	6	0	8	1	10	16	11	17	10	15	12	17
5	M	12	8	8	16	9.5	17	7	0	9	1	11	16	12	18	12	16	11	16
6	F	12	9	9	16	7	18	9	1	6	0	10	17	13	18	11	16	9	15
7	F	10	8	7	15	9.5	17	7	0	8	1	12	19	11	17	9	14	10	15
8	F	12	9	9	16	8	15	8	1	7	0	13	18	12	19	11	17	10	15
9	F	14	10	9.5	18	8	16	6	0	9	1	12	18	10	16	10	14	12	17
10	M	11	7	9	18	9.5	18	7	0	8	1	13	19	11	17	12	16	9	14

PO: preoperative, PT: postoperative

Table 2: Comparison of radiological and pedobarographic parameters

Parameter	Preoperative			Postoperative			*P*-value
	Min	Max	Mean (SD)	Min	Max	Mean (SD)	
Calcaneal pitch angle (degree)	7	9.5	8 (0.93)	15	18	16.5 (1.14)	<0.001
Meary's angle (degree)	6	9	7.5 (1.14)	0	1	0.5 (0.51)	<0.001
Heel peak pressure (N/cm^2)	10	13	11.5 (1.14)	16	19	17.5 (1.14)	<0.001
Fore foot peak pressure (N/cm^2)	9	12	10.5 (1.14)	14	17	15.5 (1.14)	<0.001

Min: Minimum, Max: Maximum, SD: Standard deviation, * paired samples t test

Clinically, children's ability to take part in athletic activities improved according to their parents' observations. Nine patients (18 feet) (90%) reported that their feet were significantly pain-free. In contrast, 1 patient (2 feet) (10%) reported minor discomfort since the implant had been inserted. In addition, their parents reported significant decrease of wear on the soles of their shoes.

Radiologically, Meary's angle improved within normal values, while the calcaneal pitch angle was within near-normal values.

Pedobarographically, medially increased center of pressure moved to laterally increased center of pressure in all feet with an improvement in terms of forefoot and heel pressures. Preoperatively, 10 feet were Viladot's grade 4 and 10 feet were Viladot's grade 3. Postoperatively, 18 feet improved to Viladot's grade 2, and 2 feet improved to Viladot's grade 3. The rate of footprint improvement is listed in Table 3.

Table 3: Degree of plantar collapse measured using Viladot's classification preoperatively and postoperatively (n=20 feet in 10 children)

Condition	Viladot's Classification				
	0	1	2	3	4
Preoperatively	0 (0%)	0 (0%)	0 (0%)	10 (50%)	10 (50%)
Postoperatively	0 (0%)	0 (0%)	18 (90%)	2 (10%)	0 (0%)

Full foot and ankle ROMs were recorded before and after surgery. None of the patients experienced major intraoperative or postoperative complications during follow-up; there was no infection, deep vein thrombosis, or implant-related problems. No patient was lost during follow-up. None of the implants were removed during the 24-month follow-up.

Discussion

In this study, we evaluated the alteration of the foot pressures and radiographic changes in the patients with symptomatic FFF and tight heel cord after simultaneous gastrocnemius lengthening and arthroereisis procedure.

Our results suggest that this procedure yields statistically significant improvement of the dynamic pedobarographic measurements including mean heel peak and mean forefoot peak pressures as well as the radiological measurements including calcaneal pitch and Meary's angle.

FFF is a common problem in children which usually does not require treatment [13]. Only 5% of the children with FFF have symptoms of plantar foot pain and muscle fatigue with increased physical activity owing to the dynamic functional changes at the lower extremities [14]. Regarding flatfoot biomechanics, the walking pressure mostly tends to distribute medially including medial arch, medial of the hindfoot, and first metatarsal head [15].

It was quite difficult to assess pedobarographic and radiological measurements immediately after cast removal at 6 weeks owing to the orientation in walking; however, the patients were orientated at follow-ups.

Pedobarographic evaluation shows that plantar pressure alterations at the foot is useful to determine abnormal walking patterns [14, 16]. In addition, the lack of radiation exposure of the children is another benefit of this evaluation. Normative data for dynamic plantar pressure measurements by pedobarographic technique was reported in several studies to define healthy feet in comparison to flatfoot deformity [17, 18]. Furthermore, numerous surgical corrective techniques have been introduced for symptomatic flatfoot [19]. Expected results with the corrective techniques may be explained as lateral shifting of foot pressures. In a dynamic pedobarographic study by Matheis et al., they reported significant changes in the medial to lateral shifting on forefoot and midfoot in terms of walking peak pressure and percentage of body weight [20]. In their comparative study of intraoperative plantar pressure evaluation by pedobarographic device, MacMahon et al. concluded that greater medial plantar pressures moved to the lateral side of the foot, especially forefoot, after corrective surgery [21]. Our study includes preoperative dynamic pedobarographic evaluation of foot, the forefoot, and heel peak pressures. Whereas higher peak pressures of the forefoot were localized on the first metatarsophalangeal joint and phalanx preoperatively, it was higher on second to fifth metatarsophalangeal joints postoperatively. In contrast, lower preoperative heel peak pressures during walking increased and were close to the normative data after surgical correction, which is consistent with literature.

With regards to corrective surgical techniques, arthroereisis stands out as a less invasive technique with the advantage of restricting the subtalar joint movement without any particular damage [19]. This periodically popularized technique has been nearly abandoned recently owing to implant-related complications and the necessity of implant removal which is considered as the most common complication [22]. In a recent study, Saxena et al. [23] reported an implant removal rate of 22.1% in 100 patients; however, the study population consists of patients older than 18 ye ars of age. It is also emphasized that an implant diameter of more than 11 mm would be a risk factor for implant removal. In our study, arthroereisis was applied to children under 14 years old, and the implant diameter was smaller than 11 mm for all cases, which is consistent with the literature. Furthermore, in weight-bearing radiographs, the mean calcaneal pitch angle increased to near-normal ranges, and Meary's angle had been corrected to the straight line between midline axis of the talus and first metatarsal rather than the convex downward position, all of which were significant. In contrast, arthroereisis procedure was performed with concomitant gastrocnemius lengthening for all cases in our study; addressing the underlying equinus deformity with gastrocnemius lengthening would provide better outcomes in children with FFF deformity. We concluded that the satisfying

changes on foot biomechanics were obtained with this combined procedure.

Numerous studies about arthroereisis procedure have evaluated the implant types, alteration of foot biomechanics, complications of implants, and walking patterns; however, there is no current data about the plantar pressure distribution in children after this procedure. The results of our study showed significant increases in both the heel and forefoot peak pressures, coinciding with the postoperative results of previous studies [15, 20].

Limitations

Nonetheless, there are some limitations to our study. First, there is no control group thus limiting the strength of the current analysis. Second, our cohort is a set of consecutive patient series in a highly specific patient group of a single surgeon in the first decade of his practice. Third, we have not used clinical outcome scores which may affect the power of study. Fourth, the study population is small owing to the low incidence of symptomatic FFF. A larger sample size might be better for detecting the prevalence of implant-related complications after this procedure. Finally, the mean follow-up period of this study is 24 months, which may be relatively short for a flatfoot series; therefore, further studies are needed to elucidate the long-term outcomes of this technique.

Conclusion

In conclusion, our study results suggest that arthroereisis procedure in combination with gastrocnemius lengthening in symptomatic FFF can yield promising short-term results if one remains faithful to the surgical technique of stabilizing the subtalar joint. However, we recommend large-scale and long-term, prospective, clinical studies to confirm the efficacy and safety of this technique.

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