

ORIGINAL ARTICLE

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Functional evaluation of bilateral arthroereisis of subtalar joint and simultaneous gastrocnemius lengthening in symptomatic flexible flatfoot in children**Zafer Atbasi***Güven Hospital, Department of Orthopedics and Traumatology, Ankara, Turkey*

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Abstract

The aim of this study was to report the radiological and pedobarographic results of 10 children's 20 feet with symptomatic flexible flat foot, who were treated with gastrocnemius lengthening with arthroereisis of subtalar joint. A total of 10 children's 20 feet (5 boys and 5 girls between 9-14-year-old) with painful feet due to the flatfoot were treated in our clinic between August 2016 and December 2018. Bilateral gastrocnemius lengthening and arthroereisis of subtalar joint was performed simultaneously. Radiological evaluation was performed by measuring calcaneal pitch angle and Meary's talusfirst metatarsal angles, pedobarographic evaluation by static and dynamic plantar heel and forefoot pressure data. The mean calcaneal pitch angle increased from $8^{\circ} \pm 0.93^{\circ}$ preoperatively to $16.5^{\circ} \pm 1.14^{\circ}$ postoperatively, and the mean Meary's talus-first metatarsal angle decreased from $7.5^{\circ} \pm 1.14^{\circ}$ preoperatively to $0.5^{\circ} \pm 0.51^{\circ}$ postoperatively. The mean heel peak pressure and the forefoot peak pressure ascended from 11.5 ± 1.14 (N/cm²) and 10.5 ± 1.14 (N/cm²) preoperatively to 17.5 ± 1.14 (N/cm²) and 15.5 ± 1.14 (N/cm²) postoperatively, respectively. Clinical evaluation revealed that 9 patient had painful feet, while 1 patient had discomfort since the implant had been inserted. Arthroereisis of subtalar joint with simultaneous gastrocnemius lengthening provides painful feet and seems to be an effective, simple and safe solution for symptomatic flexible flatfoot in pediatric patients.

Keywords: Flatfoot, pediatric, subtalar joint, arthroereisis, gastrocnemius lengthening**Introduction**

Management of flat foot treatment 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 at the pediatric population. 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. 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 extent to walking disability in children [2]. Although there is still controversy on the surgical indications and treatment

modalities, surgical intervention is recommended when the child is complaining about excessive foot pain after 8 years of age [3]. The diagnosis is also based on parental warnings about child's unwillingness of walking or contributing athletic activities due to foot pain [4,5]. Surgical management of symptomatic FFF includes various options: soft tissue procedures (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 compared to soft tissue procedures [7].

With increasing interest in foot and ankle sub-specialty and minimally invasive procedures, arthroereisis became popular and widely accepted. However, the necessity of implant removal is still a negative aspect of the procedure, and most of the current studies focus on overcoming this problem by developing new bio-absorbable implants and evaluating their effects on correction [6,8,9]. On the other hand, there is no comparative study investigating biomechanical effects of this procedure on foot plantar pressures yet.

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The aim of this study is to investigate the alterations of foot biomechanics and plantar pressures utilizing pedobarography and radiographic measurements in pediatric population who had undergone simultaneous gastrocnemius lengthening and arthroereisis procedure due to symptomatic flat foot with tight heel cord.

Materials and Methods

This retrospective study included 20 feet of 10 children (5 male, 5 female) who underwent bilateral gastrocnemius lengthening and simultaneous arthroereisis procedure for symptomatic flat feet between August 2016 and December 2018. Children between 9-14 years old with idiopathic, flexible, symptomatic FFF and gastrocnemius/gastrosoleus tightness (positive Silverskiöld test) that had not responded to adaptive footwear, orthotics or physiotherapy were included to our study. Exclusion criteria included post-traumatic, neurological or neuromuscular disorders, presence of joint hyper laxity, foot synostosis and clubfoot sequelae. Study protocol was approved by the Institutional Review Board 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 was documented by radiographs and pedobarography. 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 while restricting the dorsiflexion of the ankle joint in neutral varus/valgus position.

Radiographic Assessment

The radiographic assessment included weight-bearing anteroposterior (AP) and lateral (L) radiographs of the feet preoperatively and 6 weeks postoperatively. 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 when the presence of a coalition was suspected, and the patient was excluded from the study if present.

Pedobarographic Measurement

The pedobarographic assessment included plantar heel and forefoot (2-5 metatarsophalangeal joints and phalanges) pressures preoperatively and 6 weeks postoperatively. Footprint enlargement ratio (degree of plantar collapse) was evaluated using Viladot's classification ([0] (Figure 2,3).

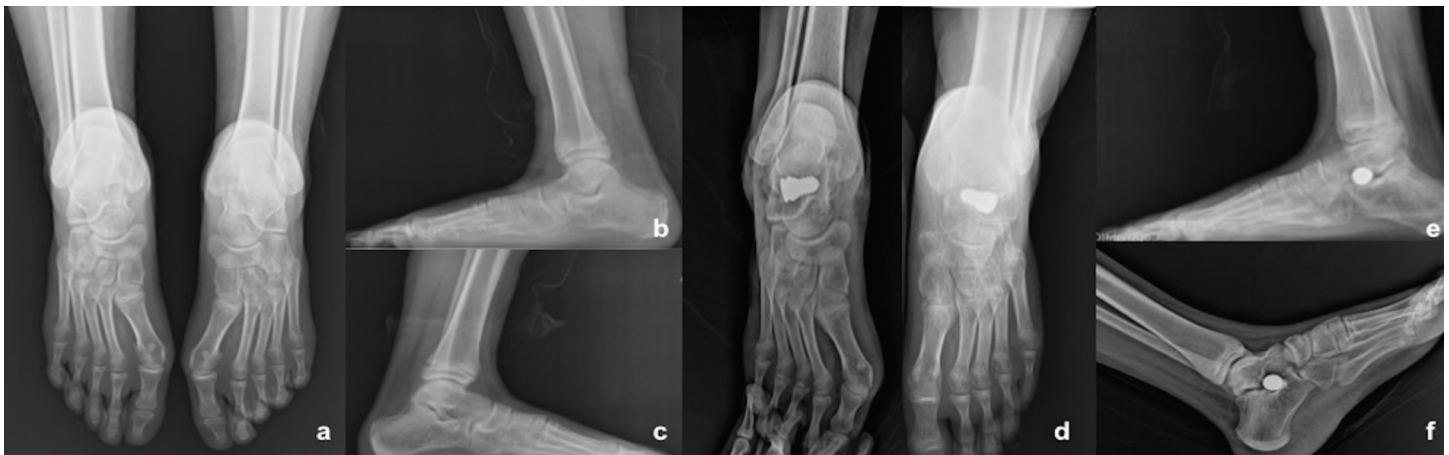


Figure 1. Preoperative a) Anteroposterior and b,c) lateral radiographs of the flatfoot of a 10- year old boy. Calcaneal pitch angle and Meary's angle was improved post-operatively d) Anteroposterior and e,f) lateral radiographs of the foot after surgical correction

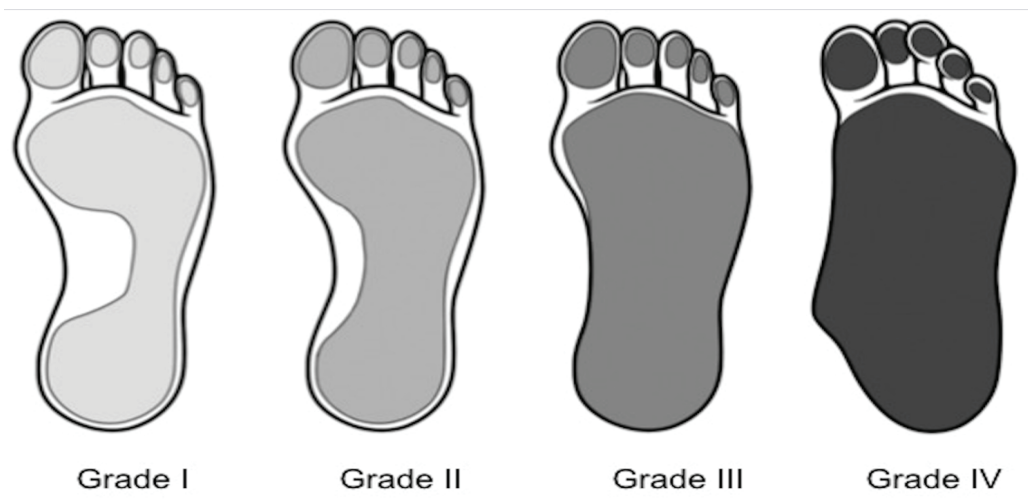


Figure 2. Footprint enlargement ratio according to Viladot (10)

Two masks of plantar foot pressures including heel and forefoot peak pressures were analyzed with the pedobarograph (footscan7®, RSscan International NV, 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 3. a) Preoperative and b) postoperative image of foot of 10-year-old girl. 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 tourniquet, a longitudinal 6-7 cm incision somewhat medial to the midline at the middle of the calf was performed. 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 is carried out and 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 sizer from small to large were inserted into the canal over the guide wire and appropriate size is selected by evaluating talotarsal mechanism until reaching the optimal hindfoot valgus which is considered < 5 degrees. After fluoroscopic assessment, 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.

Statistical Analysis

Statistical analysis was performed using the IBM SPSS for Mac version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean $\pm$ standard deviation (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 fore foot peak pressure. The interim analysis was performed by an independent statistician blinded for the treatment allocation. A p value of <0.05 was considered statistically significant.

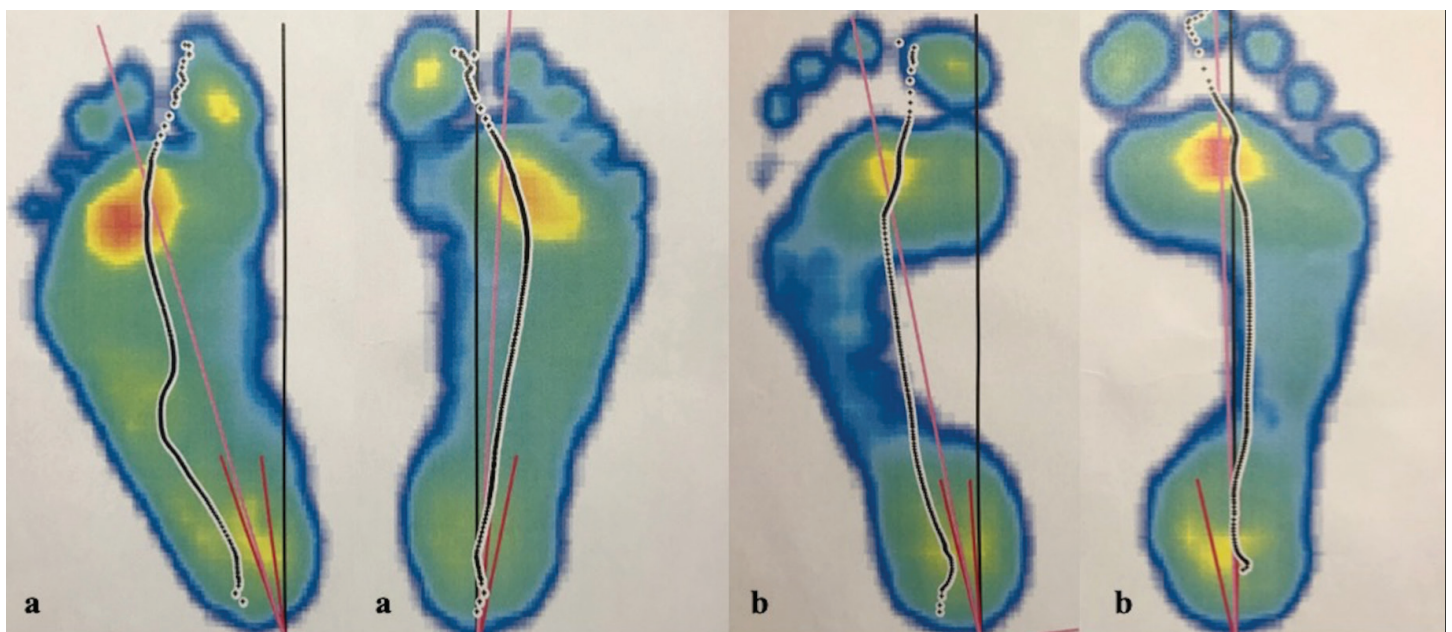


Figure 4. a) Preoperatively printed out and b) postoperative static and dynamic pedobarographic measurements of 12-year-old girl with symptomatic flatfoot. Loading of plantar foot is shifted to laterally after surgery



Figure 5. a) Anteroposterior and lateral view 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), c) Intraoperative fluoroscopic images of correct placement of guide-wire and screw.



Figure 6. Cannulated arthroereisis titanium implant. Results

Of the 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 months. Applied implant diameters were between 7-10 mm. Patients’ demographic data, radiologic and pedobarographic results are presented in Table 1. The mean calcaneal pitch angle of $8^\circ \pm 0.93^\circ$ preoperatively increased to $16.5^\circ \pm 1.14^\circ$ postoperatively ($p < 0.001$). On the other hand, the mean Meary’s angle of $7.5^\circ \pm 1.14^\circ$ preoperatively decreased to $0.5^\circ \pm 0.51^\circ$ postoperatively ($p < 0.001$).

The mean heel peak pressure of 11.5 ± 1.14 (N/cm²) preoperatively increased to 17.5 ± 1.14 (N/cm²) postoperatively and the fore foot peak pressure of 10.5 ± 1.14 (N/cm²) preoperatively increased to 15.5 ± 1.14 (N/cm²) postoperatively ($p < 0.001$ for both) (see Table 2).

Table 1. Patients’ demographic data, radiologic and pedobarographic results

Nu	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

Clinically, children's abilities to participate in athletic activities had deteriorated according to their parents' observations. 9 patients (18 feet) (90%) reported that their feet were significantly pain free. On the other hand, one 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 was improved within normal

values, while the calcaneal pitch angle was within the near-normal values. Pedobarographically, medially increased center of pressure was moved to laterally in all feet with an improvement in terms of forefoot and heel pressures. Preoperatively, 10 feet was Viladot's grade 4 and 10 feet was Viladot's grade 3. Postoperatively, 18 feet was improved to Viladot's grade 2 and 2 feet was improved to Viladot's grade 3. The rate of foot print improvement is listed in Table 3.

Table 2. Comparison of radiological and pedobarographic parameters

Parameter	Preoperative			Postoperative			p*
	Minimum	Maximum	Mean±SD	Minimum	Maximum	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

*paired samples t test

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

	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%)

All patients were discharged at the postoperative first day with a short leg soft cast. Casts were removed at the 6th week postoperatively and patients were encouraged full weight bearing as tolerated. 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 24 months follow-up.

Discussion

In this study, we evaluated the alterations 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 at 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 [11]. Only %5 of the children with FFF have symptoms of plantar foot pain and muscle fatigue with increased physical activity due to dynamic functional changes at the lower extremities [12]. Regarding flatfoot biomechanics, the walking

pressure mostly tends to distribute medially including medial arch, medial of the hindfoot and first metatarsal head [13].

Pedobarographic evaluation, which shows the plantar pressure alterations at the foot is useful to determine the abnormal walking pattern [12,14]. In addition, the lack of radiation exposure to 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 the healthy foot while comparing to flatfoot deformity [15,16]. Furthermore, numerous surgical corrective techniques have been introduced for symptomatic flatfoot [17]. 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 medial to lateral shifting on forefoot and midfoot in terms of walking peak pressure and percentage of body weight [18]. 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 [19]. Our study includes preoperative dynamic pedobarographic evaluation of foot the forefoot and heel peak pressures. While higher peak pressures of forefoot was localized on the first metatarsophalangeal joint and phalanx preoperatively, it was found higher on 2-5th metatarsophalangeal joints postoperatively. On the other hand, lower preoperative heel peak pressures during walking increased and closed to the normative data after surgical correction, which is consistent with literature. With regard to surgical

corrective techniques, arthroereisis stands out as a less invasive technique with the advantage of restricting the subtalar joint movement without any particular damage [17]. This periodically popularized technique has been nearly abandoned recently due to implant related complications and the necessity of implant removal which is considered as the most common complication [20]. In a recent study, Saxena et al. reported an implant removal rate of 22.1% in 100 patients; however, the study population consists of patients older than 18 years old. It is also emphasized that the implant diameter more than 11 mm would be a risk factor for implant removal [21]. In our study, arthroereisis was applied to children under 14 years old and 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 was 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 compared to convex downward position, those values were found statistically significant. On the other hand, arthroereisis procedure was performed with concomitant gastrocnemius lengthening for all cases in our study; addressing the underlying equinus deformity correction 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 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 ($p < 0.05$), coinciding with the postoperative results of previous studies [13,18].

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 the set of consecutive patient series in a highly specific patient group of a single surgeon in the first decade of his practice.

Third, the study population is small due to the low incidence symptomatic FFF. A larger sample size might be better for detecting the prevalence of implant related complications after this procedure. And lastly, 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 longterm 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 it remains faithful to the surgical technique of stabilizing subtalar joint. However, we recommend large-scale and long-term, prospective, clinical studies to confirm the efficacy and safety of this technique.

Financial Disclosure

There are no financial supports

Ethical approval

This study was approved by the Institutional Ethics Committee and conducted in compliance with the ethical principles according to the Declaration of Helsinki.

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