

MINIMALLY INVASIVE PROCEDURE FOR THE CORRECTION OF SYMPTOMATIC FLEXIBLE FLATFOOT IN CHILDREN

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Abstract- The aim of this study is to evaluate the medium-term results of subtalar arthroereisis for the treatment of flexible flatfoot in children and adolescents: The study includes 117 feet in 61 patients (mean age 13.27 ± 2.41 years), operated on between 2015 and 2024. The same surgical technique involving the placement of a titanium non-absorbable implant in the sinus tarsi was used in all patients. Preoperative and postoperative radiographic angular measurements of the Talo-Navicular Coverage Angle (TNCA), Calcaneal Inclination Angle (CIA), and Meary's Angle (MA) were used to assess the results. The mean follow-up period was 15.31 ± 6.46 months (min – 8 months). Statistically significant correction ($p < 0.001$) was observed in all examined parameters. The mean value of TNCA decreased from 15.39° to 7.21° , CIA increased from 11.57° to 20.36° , and Meary's Angle was reduced from 12.77° to 6.21° . A total of 14.5% (17 cases) of complications were reported during the follow-up period. The operative technique provides secure anatomical and biomechanical correction of symptomatic flatfoot in children, with restoration of the medial longitudinal arch and reduction of the hindfoot valgus position. Subtalar arthroereisis establishes itself as an effective minimally invasive method allowing for rapid patient recovery.

Keywords— flexible flatfoot, subtalar arthroereisis, children, surgical treatment

1. Introduction

Subtalar arthroereisis is a surgical technique serving as an alternative to the corrective osteotomies of the foot, lengthening calcaneal osteotomies, and soft tissue reconstructive surgeries for severe forms of symptomatic flexible flatfoot. Introduced in 1992 by Viladot, it has been routinely applied at USBALO since 2013.¹ The surgical technique we conduct is indicated mainly in cases of symptomatic flexible flatfoot in the age group of 9–18 years. The present study evaluates the results of the technique over a 10-year period and analyzes the biomechanical basis of the operation.

1.1 Surgical technique

Under spinal anesthesia, with the patient in a supine position on the operating table, a small skin incision is made over the lateral aspect of the foot in the region of the sinus tarsi, anteriorly to the anterior process of the calcaneal bone. Care should be taken to preserve the intermediate dorsal cutaneous nerve branches. The deep fascia and the capsule of the underlying subtalar joint is bluntly dissected (using a hemostatic instrument). This is followed by the insertion of a K-wire guide through the tarsal canal. The wire passes with a deviation of approximately 15° relative to the perpendicular of the sagittal plane, in an anterolateral to posteromedial direction. The guide wire is advanced to exit the medial side of the foot, leaving about 10–15 cm exposed (a small stab incision can be made for atraumaticity), and its free medial end is clamped with Kocher forceps. After fluoroscopic verification of the K-wire position, dilators of increasing size are passed over it. The goal is to achieve minimal eversion in the subtalar joint, with avoidance of overcorrection being of utmost importance. The recommended position of the calcaneus is $2\text{--}4^\circ$ valgus. Once this is achieved, an implant template corresponding in caliber to the dilator is introduced into the sinus tarsi, aiming for its medial end not to cross the axis of the talar neck in the AP view, and its lateral end to coincide with the lateral contour of the talus. Upon correct positioning of the trial implant, the definitive implant is placed, and its position is once again verified via fluoroscopy.¹

2. Materials and methods

The study includes 117 cases in 61 children with a mean age of 13.27 ± 2.41 years (24 girls and 37 boys) with symptomatic flatfoot, operated at the Pediatric Orthopedics Clinic of USBALO "Prof. B. Boychev" – Sofia during the period January 2015 – December 2024.

Weight-bearing AP and lateral radiographs were used for diagnosis and follow-up of results. Tenderness along the medial border of the foot, apophysitis of the posterior tibial muscle, and contracture of the fibular muscles were reported in all cases. Medial bulging of the talar head, due to subluxation, with skin callus formation was also observed.

Angular radiographic measurements were used to determine the severity of the deformity. On AP radiography: Talo-Navicular Coverage Angle (TNCA) with a mean value of 15.39° . On lateral weight-bearing radiography: Calcaneal Inclination Angle (CIA) - 11.57° , and Lateral Talo-1st MT Angle (MA) - 12.77° .

The data from the angular measurements are reflected in **Table 1**.

Descriptive methods and Student's t-test for paired samples were used for statistical processing of the data regarding preoperative and postoperative radiographic parameters. The applied Paired Samples t-test demonstrated high statistical significance of the changes in all examined indicators ($p < 0.001$).

3. Results

The mean follow-up period was 15.31 ± 6.46 months (min – 8 months). Preoperative TNCA decreased from $15.39^\circ \pm 5.53$ to $7.21^\circ \pm 3.52$ postoperatively. This reduction of the angle (mean difference -8.18°) indicates effective restoration of congruency in the talonavicular joint and correction of forefoot abduction (Fig. 1). The Calcaneal Inclination Angle (CIA) showed significant improvement, increasing from a mean value of $11.57^\circ \pm 4.85$ before the intervention to $20.36^\circ \pm 5.76$ after it. The increase in CIA by an average of 8.79° objectifies the elevation of the longitudinal arch and the correction of the plantar flexion of the talus. Alignment of the medial column (MA): In the measurement of Meary's Angle (Lateral Talo-1st Metatarsal Angle), a reduction from $12.77^\circ \pm 5.56$ preoperatively to $6.21^\circ \pm 3.10$ postoperatively was reported. This result (mean difference -6.56°) indicates restoration of the normal axis of the medial column and elevation of the talar head. **(Table 1.)**

Measured value	Mean	Cases (n)	Standard deviation	Standart error
TNCA postoperatively	7.21	117	3.519	.466
TNCA preoperatively	15.39	117	5.531	.733
CIA postoperatively	20.36	117	5.763	.763
CIA preoperatively	11.57	117	4.848	.642
MA postoperatively	6.21	117	3.097	.410
MA preoperatively	12.77	117	5.559	.736

Table 1. Mean values of angular measurements pre- and postoperatively

Measured Value	Paired Comparison					t	df	Sig. (p)
	Mean	Standard deviation	Standard error	95% Confidence Interval				
				lower	upper			
TNCA postoperatively / preoperatively	- 8.184	4.741	0.438	- 9.052	- 7.316	- 18.672	116	< 0.001
CIA postoperatively / preoperatively	8.789	3.783	0.350	8.096	9.482	25.130	116	< 0.001
MA postoperatively / preoperatively	- 6.564	5.488	0.507	- 7.569	- 5.559	- 12.937	116	< 0.001

Table 2. Dynamics of angular measurements in flatfoot correction.

We observed percentage improvement in all angular parameters postoperatively **(Table 2.)**

The mean duration of the operative technique is 29 ± 5.46 minutes, with the mean reported fluoroscopy time being under 20 seconds.

During the follow-up period, the following complications were reported: Incorrect indications for application of the technique (mid-tarsal instability, arthritis, rigid hind-foot equinus) – 0.85% (1 case); technical errors (implant migration, hyper- or hypocorrection) – 3.4% (4 cases); adaptation syndrome/inflammation (pain in the sinus tarsi region, soft tissue interposition) – 10.26% (12 cases). In 7 cases, implant removal was necessary after conservative anti-inflammatory therapy failed to yield improvement. In 4 of these patients, retention of the postoperatively obtained correction was observed, which we attribute to the proprioceptive action of the implant. This acts upon the sensitivity of the receptors (most of which are mechanoreceptors) located in and around the sinus tarsi.

4. Discussion

The normal structure of the foot usually develops by the age of 5–7 years. However, in 20% of children, the absence of an arch persists beyond this age, and in some cases, it becomes symptomatic.

Flatfoot represents a complex of various deformities, which include pronounced plantar flexion of the talus, subtalar eversion in a weight-bearing position, and a combination of valgus, external rotation, and dorsiflexion of the calcaneal bone relative to the talar head. The navicular bone is also abducted and displaced dorsally relative to the talar head, dragging the mid- and forefoot into abduction and supination relative to the hindfoot.³ These deformities lead to shortening of the lateral column, a condition first described by Evans (1975). Additionally, contracture of the Achilles tendon develops, which permanently fixes the hindfoot in plantar flexion and causes continued stress in the talonavicular joint and underlying soft tissues during the stance phase of gait.¹

The objective boundary between the physiological (asymptomatic) and pathological (symptomatic) variant of flexible flatfoot remains vaguely defined in scientific works. The presence of symptoms is determined by the increase of calcaneal valgus with insufficient correction upon heel rise. The clinical presentation is complemented by the collapse of the longitudinal arch of the foot, subluxation, and medial prominence of the talus at the talonavicular joint with the formation of a skin callus, as well as significant abduction of the forefoot. Shortening of the *triceps surae* muscle leads to significant worsening of complaints. Limited dorsiflexion creates a mechanical conflict in which the talus is subjected to excessive pressure from the tibia above and the calcaneus below, which forces its medial subluxation and provokes pain in the ankle joint. Increased eversion in the subtalar joint leads to calcaneofibular impingement and pain along the lateral aspect of the hindfoot and lower leg.⁴

Chronic pressure exerted by the talar head leads to progressive elongation and insufficiency of the plantar calcaneonavicular ligament (spring ligament). This process, com-

bined with the collapse of the sinus tarsi, fixes the hindfoot in a permanent valgus position. In the absence of treatment, if initially these changes are reversible and the flatfoot is flexible, it can easily become rigid due to retraction of joint capsules and secondary shortening of the Achilles tendon.¹

Based on the presented kinesiology and pathokinesiology of the pediatric foot, we believe that subtalar arthroereisis is effective in two directions:

1. Effective Biomechanical Correction: Implantation of a device in the sinus tarsi leads to statistically significant ($p < 0.001$) restoration of the medial longitudinal arch and reduction of the hindfoot valgus deformity. This is objectified by the lasting improvement of TNCA, CIA, and MA.

2. Dual Mechanism of Action: The achieved results support the thesis that arthroereisis acts not only as a passive mechanical limiter of eversion but also as a proprioceptive stimulator, aiding the active remodeling of the foot during growth.

Although flatfoot affects a significant percentage of the pediatric-adolescent population, reaching 45–70% in children between 2 and 5 years and decreasing to about 15–20% at age 10, there is no uniform opinion regarding the necessity of treating the flexible form and the appropriate age for surgery.

Bouchard and Mosca note that in the absence of pain, flexible flatfoot is a physiological condition and does not require treatment.⁴ This assertion finds support among a number of authors. Children with asymptomatic flexible flatfoot should be observed clinically for the appearance of symptoms and signs of progression. Continued development of the condition requires re-evaluation to identify, another potential underlying disease. Since growth-related changes in foot shape and mobility continue until approximately eight years of age, developmental problems are expected to resolve by this age.⁵ Thus, the presence of pronounced flatfoot in children over 8 years of age requires further evaluation, despite the lack of symptoms.

Evans and Rome (2011) conclude that operative treatment is rarely required for pediatric flatfoot. According to Viladot (1992), it is indicated in about 1.2% of all cases of flexible flatfoot. The consensus of author opinions suggests that if conservative methods have failed and the child has no relief of symptoms, surgery is indicated.⁶ However, the physician should not be solicited towards operative treatment based on parental demands to have a child with a "normal foot".⁷

Historically, Haraldson (1962) is considered the pioneer in subtalar joint arthroereisis, placing a bone wedge in the sinus tarsi. With the establishment of the modern model for arthroereisis introduced by Viladot in 1992, subtalar arthroereisis has proven to be a method with minimal invasiveness and encouraging results, becoming an established procedure for the treatment of flexible pediatric flatfoot.^{6,7,8}

The main mechanisms of correction via STA include mechanical stabilization and proprioceptive stimulation⁷. A consensus opinion in the literature is that regardless of the implant type, the method is applicable only in patients with preserved ability for active correction of the deformity.⁵

The results observed in our series are largely confirmed by the literature. The complication rate observed in our series is fully comparable with literature data (**Table 3**). Based on the literature analysis, it is noteworthy that the Talo-Navicular Coverage Angle (TNCA) is a relatively less frequently used criterion in the assessment of flatfoot.

Ruiz (2019) reports an improvement in TNCA from 31.8 to 14.37 for the left foot and from 34.12 to 16.12 for the right. ⁸

	MA preoperatively	Ma postoperatively	CIA preoperatively	CIA postoperatively	Percentage of complications
Tan JHI ⁹	16.67	5.267	12.5	15.7	8.7%
Smith ¹⁰	17.1	7.4	12.2	15.7	7.1
Current study	12.77	6.21	11.57	20.36	14.5

Table 3. Comparison of own results with those published in world literature.

5. Conclusion

In the present study, changes in quality of life scales were not reported. However, we accept that the placement of an implant in the sinus tarsi leads to radiographically statistically significant restoration of the medial longitudinal arch and reduction of the hindfoot valgus deformity (**Fig. 1**), (**Fig. 2**). The achieved results support the thesis that arthroereisis acts not only as a passive mechanical limiter of the eversion but also as a proprioceptive stimulator, aiding the active remodeling of the foot during growth. The technique ensures reliable and long-lasting correction with minimal trauma to the patient.



Fig.1: ♂ M.G. at 12 years of age with flexible symptomatic planovalgus before and after SA (Subtalar Arthroereisi) using a titanium subtalar implant



Fig. 2: 12 y.o. ♂ M.G. (clinical presentation).

6. References

1. Kehayov R. Calcaneal Distraction Osteotomy for the Correction of Symptomatic Flatfoot in Children and Adolescents [dissertation]. Sofia: Medical University of Sofia; 2021.
2. Mosca VS. Flexible flatfoot in children and adolescents. *J Child Orthop*. 2010;4(2):107-121.
3. Galán-Olleros M, Del Baño Barragán L, Figueroa MJ, et al. Outcomes of the "Calcaneo-Stop" Procedure for Treating Symptomatic Flexible Flatfoot in Children: A Systematic Review and Meta-Analysis of 2394 Feet. *Foot Ankle Surg*. 2024;30:535-545.
4. Bouchard M, Mosca VS. Flatfoot deformity in children and adolescents: surgical indications and management. *J Am Acad Orthop Surg*. 2014;22(10):623-632.
5. De Pellegrin M, Moharamzadeh D, Strobl WM, et al. Subtalar extra-articular screw arthroereisis (SESA) for the treatment of flexible flatfoot in children. *J Child Orthop*. 2014;8:479-487.
6. Vogt B, Toporowski G, Gosheger G, et al. Subtalar Arthroereisis for Flexible Flatfoot in Children-Clinical, Radiographic and Pedobarographic Outcome Comparing Three Different Methods. *Children (Basel)*. 2021;8(5):359.

7. Bernasconi A, Lintz F, Sadile F. The role of arthroereisis of the subtalar joint for flatfoot in children and adults. *EFORT Open Rev.* 2017;2:438-446.
8. Ruiz-Picazo D, Jiménez-Ortega P, Doñate-Pérez F, et al. Radiographic and Functional Results following Subtalar Arthroereisis in Pediatric Flexible Flatfoot. *Adv Orthop.* 2019;2019:5061934.
9. Tan JHI, Tan SHS, Lim AKS, Hui JH. The outcomes of subtalar arthroereisis in pes planus: a systemic review and meta-analysis. *Arch Orthop Trauma Surg.* 2021;141:761-773.
10. Smith C, Zaidi R, Bhamra J, et al. Subtalar arthroereisis for the treatment of the symptomatic paediatric flexible pes planus: a systematic review. *EFORT Open Rev.* 2021;6(2):118-129.

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