International Surgery Journal
Gennadiy KA et al. Int Surg J. 2025 Jun;12(6):904-909
http://www.ijsurgery.com
pISSN 2349-3305 | eISSN 2349-2902

DOI: https://dx.doi.org/10.18203/2349-2902.isj20251529

Original Research Article

Evaluation of degree of correction by anterograde calcaneo-stop method in the management of juvenile flexible flatfoot: a retrospective study

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Received: 12 May 2025
Accepted: 26 May 2025

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ABSTRACT

Background: Flexible flatfoot is a frequent foot deformity among pediatric population. The anterograde calcaneo-stop method (ACSM) has been published to be beneficial in short-term studies. The purpose of this study to assess the degree of correction following the ACSM in the management of juvenile flexible flatfoot.
Methods: The retrospective study consists of 400 surgical procedures performed from the period of January 2013 to December 2023 in 100 patients (200 ACSM and 200 removal of calcaneo-stop implant surgeries), which were evaluated clinically, and instrumental diagnostic techniques such as photoplantography and pedobarography were implemented. The inclusion criteria of this study comprises of patients with ages from 6 to 16 years,with symptomatic flexible flatfoot deformity along with absence of responsive to bilateral conservative treatment and the exclusion criteria includes the following; patients with ages below 6 years and above 16 years, the time ceased of 3 years after screw implantation, patients with other musculoskeletal deformities.
Results: The 200 surgical interventions performed on bilateral flexible flatfoot were evaluated in 100 patients after their removal of the screws following the ACSM, showed no signs of loss of degree of correction; which were further evaluated by degree of connective tissue dysplasia according to Wynne-Davies, radiologically by photoplantography and pedobarography.
Conclusions: The ACSM is a simple surgical treatment, which is minimally invasive in nature used for symptomatic juvenile flexible flatfoot. The collected data stipulated a sufficient degree of correction by ACSM in the management of flexible flatfoot in the pediatric population.

Keywords: Flexible flatfoot, Talus, Pediatric orthopedics, Anterograde calcaneo-stop method, Degree of correction

INTRODUCTION

The most prevalent foot deformity presenting in children is flexible flatfoot.[1] There are many depictions of longitudinal flatfoot, but the presence of flattening of the longitudinal arch, heel eversion, and forefoot abduction are usually accepted criteria for this deformity. In the flexible form, there is the recovery of the longitudinal arch during standing on the toe or when performing the windlass test.

Physiologic flatfoot is rather prevailing and is originated by the presence of a "fat cushion" in the longitudinal arch area, which undergoes involution until the age of 5-6 years.[2,3] Currently, there are no prospective studies on the long-term consequences of flexible flatfoot without correction. However, some studies have revealed the impairment foot biomechanics led to the development of many degenerative skeletal disorders and also contributed to different foot malformation.[4-6]

In the presence of symptomatology: with the form of pain or fatigue in the lower extremities, conservative treatment with the form of plantar orthoses (supinator insoles) is prescribed in patients with the flexible flatfoot. However, currently there are no evidence-based studies with confirming effects of conservative therapy.[7-9]

The existing methods of surgical correction of flexible flatfoot are categorized into three groups: soft-tissue surgeries, osteotomies of the foot bones, combination of soft-tissue surgeries with interventions on bone structures; surgeries limiting movements in the joints of the foot (extra- and intra-articular arthrodesis, arthroeresis of the subtalar joint, calcaneo-stop method). Interventions on the soft tissues of the foot are not performed in isolation, as the number of recurrences is high. Osteotomies of the bones of the foot are very traumatic interventions, with unstudied long-term results of correction.[10] Arthrodesis of the joints of the foot is not recommended in children, as it impairs the biomechanics of the foot, which has consequences in the form of degenerative changes in adjacent joints and overlying parts of the musculoskeletal system. Therefore, this type of intervention is performed in children after completion of ossification of the foot skeleton in case of deformity recurrence.[11]

Arthroeresis is a very promising technique that has proven itself in pediatric orthopedics. The essence of the method is to block excessive pronation of the subtalar joint from a minimally invasive approach. However, despite the advantages of the method, many of its complications and disadvantages have been described, such as aseptic necrosis of the block of the talus, fractures of the calcaneus and talus bones, sinus tarsi syndrome, synovitis of the subtalar joint, formation of cysts in the body of the talus bone, and pain in the calcaneal region.[12] Taking into account the above complications, we used the minimally invasive method of surgical correction of flexible flatfoot in children-ACSM.

The purpose of this study was to investigate the early and long-term results of degree of correction of flexible flatfoot in children by ACSM.

METHODS

This retrospective study took place at the pediatric orthopedics department of the Grodno regional children's clinical hospital from the period of January 2013 to December 2023 employing an open-label, prospective, and comparative methodology. During the period, 200 surgical interventions on both feet simultaneously were performed on the basis of in 100 patients by ACSM. The gender distribution was 60 boys and 40 girls. The mean age recorded was 11 years (from a range of 6 to 16 years). The examination of patients was done immediately before surgical intervention, following 3 months, 6 months, and 12 months after surgical care. Inclusion criteria of this study were: patients with symptomatic flexible flatfoot deformity (with the presence of pain, impaired optimal function and presence of limitations of movement or skin lesions) together with a vague response to conservative treatment (bilateral surgical maneuvers), patients with age group ranging from 6 to 16 years. Exclusion criteria included the patients diagnosed with positive neurological or neuromuscular disorders, presence of hereditary or post-traumatic flatfoot, with comorbidities such as diabetes or systemic conditions like immunological diseases, patients with ages below 6 years and above 16 years, the time elapsed of 3 years after screw implantation.

For examination of the patients, the clinical assessment of the degree of connective tissue dysplasia according to Wynne-Davies was implemented. Other methods included radiological, photoplantographic, pedobarographic techniques and statistical analysis with the assistance of StatTech v. 4.7.2 software package, Russia (using non-parametric methods) and MS excel were also used.

The following radiologic parameters were evaluated: angle of talus-I-metatarsal (Meary's angle), angle of longitudinal arch, angle of talar declination, angle of lateral talocalcaneal, angle of anteroposterior talocalcaneal (Kite’s angle), angle of calcaneal inclination, angle of talus-II-metatarsal, degree of opening of the tarsal sinus, talonavicular coverage angle. Treatment results were evaluated 6 months, 1 year and 3 years after the removal of the screws.

The photoplantograms were evaluated: forefoot print width, midfoot print width, hindfoot print width, outer foot print length, inner foot print length, Chipaux-Smirak index (ratio of midfoot print width to forefoot print width), Staheli longitudinal arch index (ratio of the size of the narrowest part of the footprint in the midfoot to the widest part in the hindfoot), Clarke's angle (formed by the line connecting the extreme medial points of the footprint and the line tangent to the most anterior point of the footprint contour of the inner longitudinal arch of the foot).

The distribution of plantar pressure was measured during pedobarography, with the assistance of the foot division into 5 biomechanical zones: A-the toe zone corresponding to the position of the phalanges of the toes; B-the metatarsal zone representing the metatarsophalangeal joints and the projection of the foot roll in the direction of mechanical axis; C, D-the zones of the medial area, established by the Chopart line and separated by a longitudinal line following the calcaneal tubercle through the middle of the distance between the heads of the 1st and 5th metatarsal bones into medial, or spring (C), and lateral-support (D) parts, reflecting the condition of the subtalar joint and the probabilities of the shock-absorbing component; E-the heel zone, which is considered the main axial support.

The structural analysis of the integral load graphs revealed the evaluation of rhythmicity, smoothness, expression of anterior (heel) and posterior (toe) thrust, as well as the main minimum of the load, and particularly attention was given to the symmetry of the graphs. In the normal range, the results of integral load graph should have well prominent anterior and posterior thrusts, together with the main load minimum.

During the statistical analysis, we evaluated the obtained data for normality of distribution (with the assistance of Shapiro-Wilk, Kolmogorov-Smirnov and Lilliefors tests). In case of normal distribution of the obtained data, the mean and standard deviation were determined, statistical significance was assessed using Student's t-test for dependent variables. In case of atypical distribution, the median with upper and lower quartiles were specified with the method of non-parametric statistics being used to compare dependent variables with application of Wilcoxon test.

All procedures were strictly adhered to ethical standards set forth by both institutional and national committees on human experimentation, aligning with the Helsinki declaration of 1975 and its 2013 revisions.

RESULTS

Before the operation, the median of heel valgus angle was 14° (7.8/21.4) after 12 months 5.1° (0/10.3) (Wilcoxon test; $p<0.0001$).

The data received from Table 1 and 2 depicted the highly statistically significance. Thus, further accommodating the prove of degree of correction of flexible flatfoot following ACSM.

During comparison between the pedobarographic data obtained before and after ACSM, it was shown that no statistically significant deviations in the distribution of pressure under the plantar surface of the foot were present. (Table 3).

There were also no significant changes in the total center of mass displacement plot.

Table 1: Changes in radiographic parameters before and 1 year after operation.

Parameters	Before operation	After operation	Statistical significance, p
Talo-I-metatarsal angle	161.5°±6.9	174.7°±5.3	p<0.00001
Longitudinal arch angle	152.3°±5.4	141.3°±4.8	p<0.0001
Talar declination angle	33.7°±5.6	25.6°±3,0	p<0.0001
Anteroposterior talocalcaneal angle	43.8° (46.4/39.5)	35.4° (37.7/31.2)	p<0.0001
Lateral talocalcaneal angle	44.9° (32.9/60.3)	37.7° (25,0/49,3)	p<0.0001
Calcaneal inclination angle	11.1° (4.2/15.1)	13.9° (6.4/20.6)	p<0.0001
Talo-II-metatarsal angle	24.1° (11.4/41.4)	0° (от -5 до 19)	p<0.0001
Degree of opening of the tarsal sinus	5.4 (2.3/15.1)	10.9 (4.3/20.5)	p<0.0001
Talonavicular coverage angle	27.2° (6.5/51.6)	8.5° (0/25.3)	p<0.0001

Table 2: Changes in photoplantographic parameters before and 1 year after operation.

Parameters	Before operation	After operation	Statistical significance, p
Forefoot print width (mm)	74.2±10.0	77.6±11.2	p=0.008
Midfoot print width (mm)	43.1±15.7	31.2±7.0	p=0.0002
Hindfoot print width (mm)	42.8±6.5	44.4±7.5	p=0.02
Outer foot print length	105.1 (77.3/137.8)	110.7 (80.3/148.8)	p=0.0001
Inner foot print length	127.8±15.4	131.5±14.4	p=0.59
Index Chipaux-Smirak	0.57 (0.31/0.83)	0.37 (0.24/0.47)	p<0.0001
Longitudinal arch index Staheli	0.85 (0.62/2.02)	0.74 (0.44/0.94)	p<0.0001
Clarke angle	25.4° (10.5/48.8)	47.8° (31.4/56.0)	p=0.00002

Table 3: Distribution of pressure on the plantar surface before and 1 year after operation.

Zones of plantar surface	Pressure before ACSM (%	Pressure after ACSM (%)	Statistical significance, p
Zone A	17 (15.4/18.1)	21 (16.3/22.5)	p=0.003
Zone B	27 (25.2/28.4)	32 (26.5/30.3)	p=0.0001
Zone C	6 (4.6/7.5)	2 (1.2/3.2)	p=0.0001
Zone D	19 (17.8/20.2)	21 (18.4/24.2)	p=0.004
Zone E	32 (31.2/33.4)	34 (32.4/36.1)	p=0.001

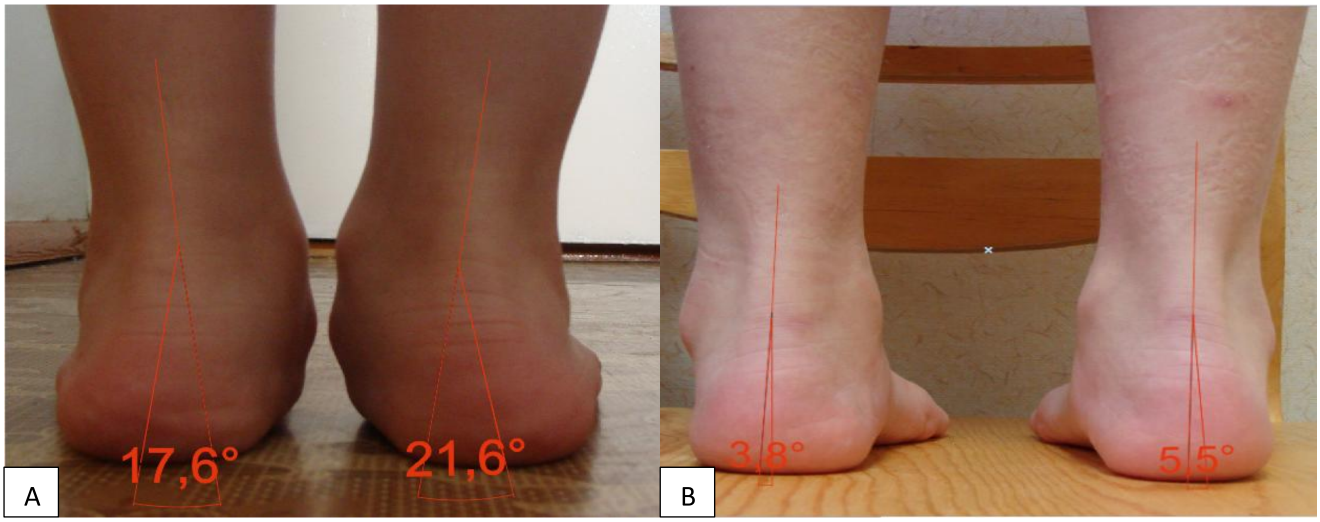

Figure 1 (A and B): A-Preoperative photograph of patient N. (8-year-old) diagnosed with bilateral flexible flatfoot. Seen significant valgus of the calcaneus; B-Postoperative photograph of the same patient 1 year after operation, present correction of the longitudinal arch and the valgus position of the heel.

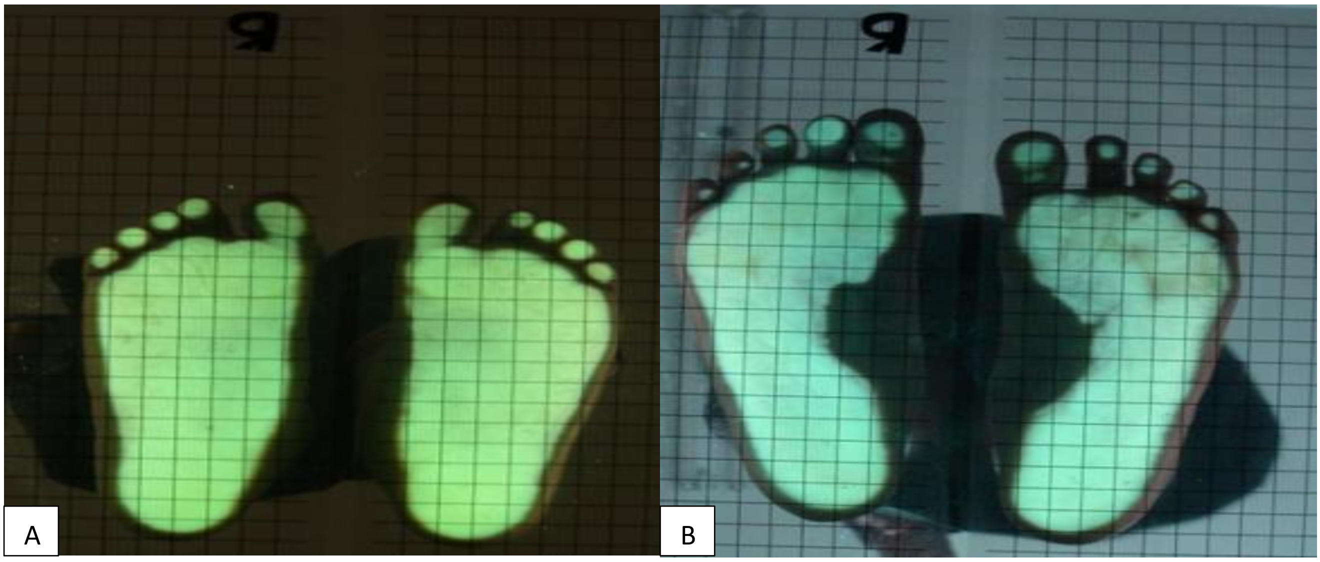

Figure 2 (A and B): A-Preoperative photograph of patient N. (8-year-old). Seen absence of the longitudinal arch; B-Postoperative photograph of the same patient 1 year after operation, present correction of the longitudinal arc.

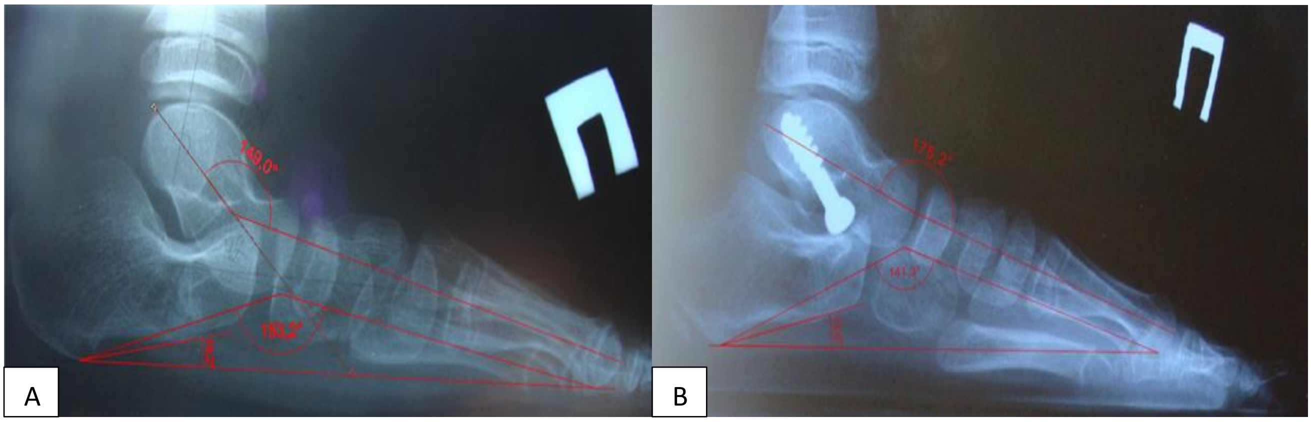

Figure 3 (A and B): Preoperative radiographs of patient N. (8-year-old). A-Seen absence of the longitudinal arch. B-Postoperative photograph of the same patient 1 year after operation, present correction of the longitudinal arch.

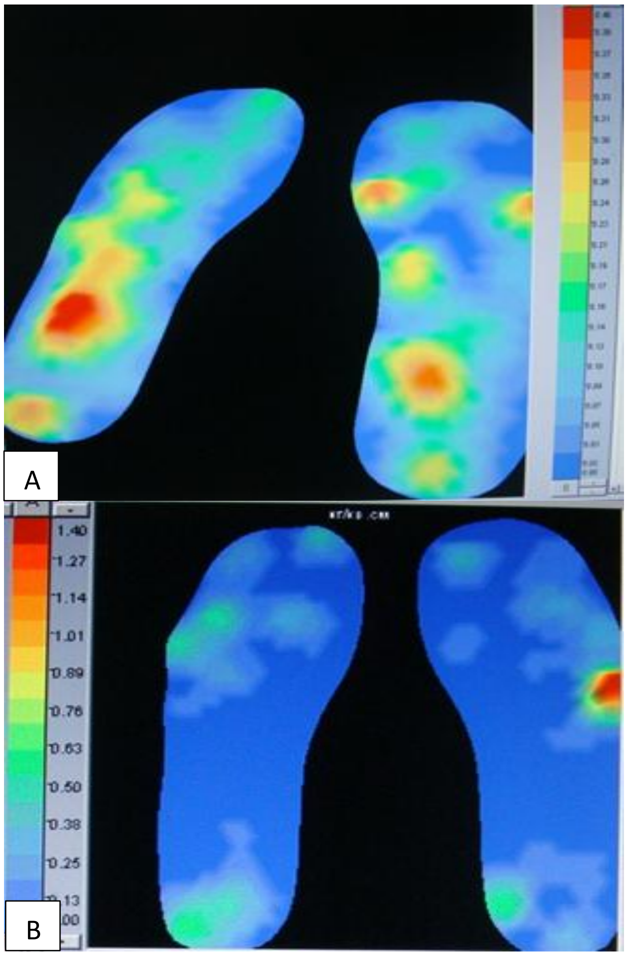

Figure 4 (A and B): Pedobarographic distribution of loads on the plantar surface before and 12 months after operation.

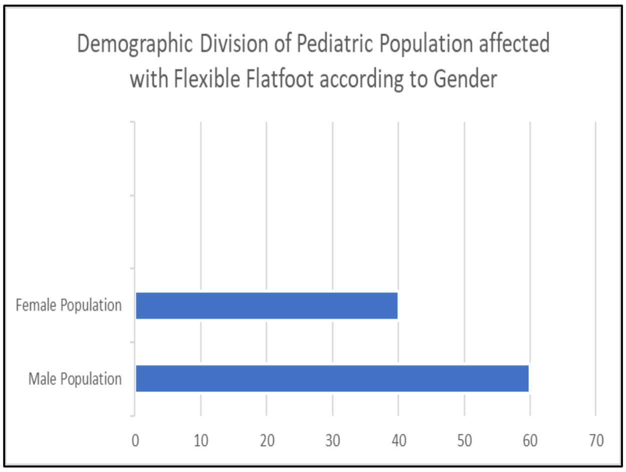

Figure 5: Demographic division of pediatric population affected with flexible flatfoot according to gender.

DISCUSSION

Many authors have elaborated the proprioceptive function of implants fixated in the tarsal sinus.[8,9] The function of the tarsal sinus as a powerful neurosensory field is confirmed by the observations of Pisani, who described a phenomenon in which the deformity of the unoperated contralateral foot can be corrected.[10]

Limited publications reviewed upon the results of the treatment pediatric flexible flatfoot by ASCM. Roth et al reported that correction of the flexible flatfoot the longitudinal arch of the foot as well as the heel valgus remained corrected in 86 feet (91%) after removal screws.[12]

Kellermann et al surmised that patient satisfaction rate after ACSM was excellent for 33 feet of 19 children, good for eight feet of five children, and poor for either foot of one child.[13]

Dibello et al revealed that the ACSM is a valuable technique, which improves their quality of life and the family wellbeing.[14]

Results of the investigation of Pavone et al revealed juvenile patients who received the ACSM had reported resultant to be satisfactory in accordance with clinical and radiological evaluations.[15]

This retrospective study's results of the talo-I-metatarsal angle (Meary) from 161.5° to 174.7° are correlated with data observed by Kellermann and Terebessy, where an improvement of the Meary's angle from 157.5° to 171° on 28 cases following anterograde insertion of AO screw into the talus.[13,16] The pedobarographic data is the same as the obtained data from Kellermann and Terebessy, where a lateral shift of the load on the sole and the decreased function of the great toe was found following the ACSM.

From the perspective of gender of pediatric population affected with flexible flatfoot, 60 out of 100 (60%) pediatric patients were males and 40 out of 100 (40%) pediatric patients were females; thus, showing a demographic shift to male population. This finding confirms the male gender played a role as one of the significant predisposing factors for flexible flatfoot in pediatric population.

Limitations

This study has some limitations. It lacked a control study group, with a biased possibility in clinical evaluation and the absence of objectively measurable parameters were noted.

CONCLUSION

The collected data surmised a sufficient degree of correction by anterograde calcaneo-stop method in the management of juvenile flexible flatfoot. Our prospective, short-term results seem to correlate well with the results of similar methods of surgical correction of flexible flatfoot. The analysis of errors and complications revealed the necessity of strict compliance with the technique of surgical intervention, careful preoperative planning.

Recommendations

Early diagnosis of flexible flatfoot in the pediatric population and timely management may improve the quality of life and prognosis of the patients with a better degree of correction.

ACKNOWLEDGEMENTS

Authors would like to thank to medical staff at the orthopedic department in the general pediatric hospital in Grodno, Belarus.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Gennadiy KA, Direcksze NDKN, Yogarajah K, Yohanathan N, Afham MNM, Ahmath ANN, et al. Evaluation of degree of correction by anterograde calcaneo-stop method in the management of juvenile flexible flatfoot: a retrospective study. Int Surg J 2025;12:904-9.