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Original Research Article

Efficacy of the anterograde calcaneo-stop method in the management of flexible flatfoot in children

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ABSTRACT

Background: Flexible flatfoot is one of frequent foot deformity among pediatric population. The calcaneo-stop procedure has been reported to be effective in short-term studies when conservative treatment is not successful. The aim of this study to evaluate the efficacy after removal of screws following the anterograde calcaneo-stop procedure in the treatment of flexible flatfoot in children.
Methods: This retrospective study consists of 260 calcaneo-stop procedures performed from the period of January 2016 to December 2024 in 65 patients (130 anterograde calcaneo-stop surgeries and 130 removals of calcaneo-stop implant surgeries), which were evaluated clinically, and instrumental diagnostic techniques such as radiography, photoplantography and pedobarography were implemented. The inclusion criteria of this study consist of patients with symptomatic flexible flatfoot, patients with ages from 6 to 14 years, patients with informed consent, patients with negative Wynne-Davies joint hypermobility test and the exclusion criteria of this study includes the following; patients with ages below 6 years and above 14 years, the time elapsed of 3 years after screw implantation, patients with other skeletal deformities, patients without informed consent.
Results: Out of the 130 surgical interventions performed on bilateral flexible flatfoot, which were evaluated in 65 patients after removal the screws following the anterograde calcaneo-stop procedure, revealed no signs of loss correction; which were further evaluated by radiography, photoplantography and pedobarography.
Conclusions: The calcaneo-stop procedure is the least invasive and simplest surgical treatment for symptomatic flexible flatfoot in children. The collected data indicated a sufficiently high efficiency of anterograde calcaneo-stop method in the treatment of flexible flatfoot in children.

Keywords: Flexible flatfoot, Cancellous screws, Talus, Pediatric orthopedics, Calcaneo-stop procedure

INTRODUCTION

Flexible flatfoot is the most prevalent foot deformity in children.[1] There are many definitions of longitudinal flexible flatfoot, but the presence of flattening of the longitudinal arch, heel eversion, and forefoot abduction are generally accepted criteria for this deformity. Flexible (mobile) flatfoot denotes the restoration of the longitudinal arch when standing on the toe or when performing the first toe extension test (Jack's test). Physiologic (asymptomatic) flatfoot is very common and is caused by the presence of a "fat pad" in the longitudinal arch area, which undergoes involution until the age of 5-6 years.[2,3] Currently, there were no prospective studies on the long-term consequences of flexible flatfoot without correction. However, there are studies indicating that disturbed foot biomechanics leads to the development of many degenerative skeletal diseases and also contributes to other foot deformities.[4,5] In the presence of symptoms like pain or fatigue in the legs and foots, prescribed conservative treatment in the form of plantar orthoses - supinator insoles and physiotherapy are indicated. However, the absence of evidence-based studies suggest there are no confirmation for the effect of conservative therapy.[6-8] The existing methods of surgical correction of non-fixed longitudinal flatfoot are divided into three groups: soft-tissue surgeries, osteotomies of the foot bones, combination of soft-tissue surgeries with interventions on bone structures; and another group of surgeries such as limiting the movements in the joints of the foot (extra- and intra-articular arthrodesis, arthrodesis 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.[9] Arthrodesis of the joints of the foot nowadays used very rarely, because it disturbs 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.[10] Arthrodesis is a very encouraging 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 this method, many of its complications and disadvantages have been described, such as aseptic necrosis of the body 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 and pain in the calcaneal region.[11] Taking into account the above complications, we applied a minimally invasive method of surgical correction of flexible flatfoot in children - anterograde calcaneo-stop method. The aim of our study was to investigate long-term prognosis of correction of flexible flatfoot in children by anterograde calcaneo-stop method.

METHODS

This retrospective study conducted during the period from January 2016 to December 2024, consisting a total of 260 surgical procedures, which included 130 surgical interventions performed on the basis of the pediatric orthopedics department of the Grodno Regional Children's Clinical Hospital in 65 patients to remove the screws following the primary 130 anterograde calcaneo-stop procedures. Removing of the screws performed after 3 years following the primary operation. We performed our investigation 3 years later in patient after removal of screws. The gender distribution were 49 boys and 16 girls. The average age was 10.2 years (from 6 to 14 years). The indications for the removal of the screws were: negative Wynne-Davies joint hypermobility test used to assess the degree of connective tissue maturity, absence of the screw head support on the anterior process of the calcaneal bone, and the time elapsed after implantation of the screw more than 3 years. The ethical approval (informed consent) was obtained by all the subjects involved in this study.

The inclusion criteria of this study consist of patients with symptomatic flexible flatfoot, patients with ages from 6 to 14 years, patients with informed consent, patients with negative Wynne-Davies joint hypermobility test and the exclusion criteria of this study includes the following; patients with ages below 6 years and above 14 years, the time elapsed of 3 years after screw implantation, patients with other skeletal deformities, patients without informed consent.

We used the following methods to study the patients: clinical, radiographic, photoplantographic, pedobarographic and statistical processing of the materials were carried out using the StatTech v. 4.7.2 software package, Russia, using non-parametric methods and Microsoft excel.

The following radiologic parameters were evaluated: Talus-I-metatarsal angle (Meary's angle), longitudinal arch angle, talar declination angle, lateral talocalcaneal angle, anteroposterior talocalcaneal angle (Kite’s angle), calcaneal inclination angle, talus-II-metatarsal angle, degree of opening of the tarsal sinus, talonavicular coverage angle. Treatment results were evaluated in 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).

To quantify the distribution of plantar pressure during pedobarography, we used the division of the foot into 5 biomechanical zones: A - toe zone corresponding to the location of the phalanges of the toes; B - metatarsal zone capturing the metatarsophalangeal joints and the projection of the mechanical axis of the foot roll; C, D - zones of the medial area, delimited by the Chopart line and divided by a longitudinal line running from 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 possibilities of the shock-absorbing component; E - heel zone, which is the main axial support.

The analysis of the structure of the integral load graphs consisted in the evaluation of rhythmicity, smoothness, expression of anterior (heel) and posterior (toe) thrust, as well as the main minimum of the load, and attention was paid to the symmetry of the graphs. In the norm, the integral load graph should have well pronounced anterior and posterior thrusts, as well as the main load minimum.

When performing statistical analysis, we evaluated the obtained data for normality of distribution (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 non-normality of distribution, the median with upper and lower quartiles was indicated, and the method of non-parametric statistics was used to compare dependent variables using the Wilcoxon test.

Surgical technique

The following surgical instruments are required to perform the surgical aid: scalpel blades no. 10, 11 or 15, mosquito forceps, bone awl, set of steel cancellous screws 6.5 mm in diameter, length from 25 to 35 mm, hexagonal screwdriver, hooks, cutting needle, nonabsorbable suture material.

The operation is performed under general or spinal anesthesia, depending on the age and general medical status of the child in a supine position. Deformity correction is usually performed simultaneously on both feet. The scheme of the operation is shown in Figure 1.

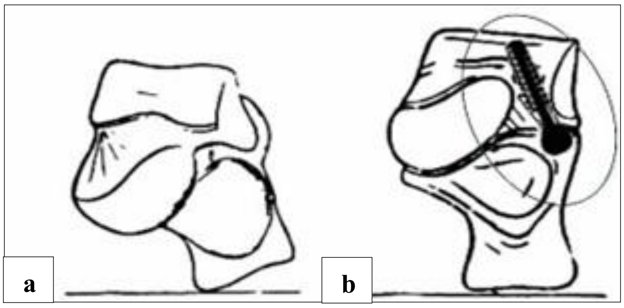

Figure 1: (a) Excessive pronation of the subtalar joint results in medial displacement and plantar flexion of the head of the talus, and (b) implantation of a cancellous screw blocks excessive pronation of the subtalar joint.

A transverse access up to 1 cm long is made along the skin fold above the level of the tarsal sinus 1 cm anteriorly and downward from the external ankle (Figure 2a). Only the skin is dissected, which prevents damage to the n. suralis and n. cutaneus intermedius. Subcutaneous fatty tissue and superficial fascia are dissected bluntly using a "mosquito" forceps. Next, a bone awl (4 mm in diameter) is used to create the canal in the distal part of the anterior surface of the lateral process of the talus. The most important point of the intervention is the choice of the entry point of the screw in the lateral process of the talus and determination of its working length. The direction of the bone canal should be such that the head of the screw lies on the upper part of the anterior calcaneal process, so that the implanted screw creates a restriction of excessive pronation in the subtalar joint, i.e. perpendicular to the axis of its movement. The canal in the talus is formed in the oblique direction from bottom to top, from front to back, from outside to inside at an angle of 45±5° in the frontal plane and 30±5° in the sagittal plane (Figure 2b). This is followed by X-ray control of the canal direction in two projections. It is preferable to use an electron-optical transducer for X-ray control.

After X-ray control, a cancellous screw is implanted into the body of the talus (Figure 2c). The degree of correction is determined by the amount of screw immersion, the longer the working part, the greater the supination of the subtalar joint and, accordingly, the more pronounced the longitudinal arch.

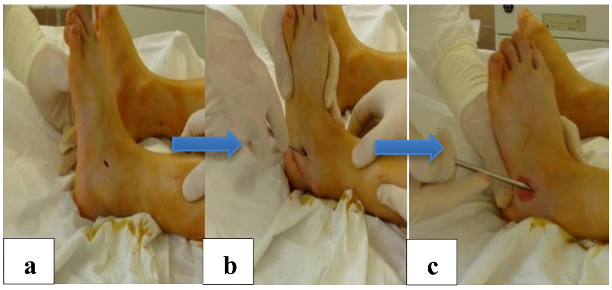

Figure 2: (a) Surgical approach, (b) formation of a canal in the body of the talus, and (c) screw implantation.

After screw implantation, the volume of pronation and supination movements in the subtalar joint is assessed. The final evaluation of the screw position is performed by X-ray control. If deformity correction is achieved and the screw position is optimal, then hemostasis, layer-by-layer wound suturing, and aseptic dressing are performed.

In the postoperative period, full body weight bearing was allowed immediately after the pain syndrome decreased (on average on the 3rd day). One of the advantages of the proposed method of correction is the absence of the need for immobilization in the postoperative period. The sutures were removed on the 10th-12th day.

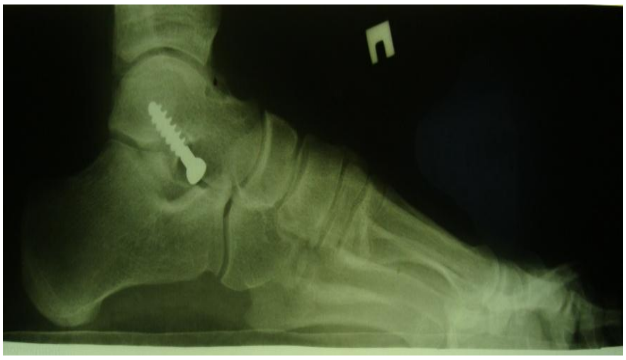

Figure 3: Position of the screw after implantation.

RESULTS

Before removal of screws, the median of heel valgus angle was 4.7° (1.2/7.5) after 4.8° (1.4/7.2) (Wilcoxon test; p=0.48). The results of changes in radiographic parameters before and 3 years after screw removal are presented in Table 1.

The results of the change in photoplantographic parameters are presented in Table 2.

Comparing the pedobarographic data obtained before and after screw removal, there were no statistically significant deviations in the distribution of pressure under the plantar surface of the foot (Table 3). Furthermore, there were also no significant changes in the total center of mass displacement plot.

The following data revealed the changes after the removal of screws which were not statistically significant, Therefore, indicating the presence for no loss of correction (Figures 4-6). Furthermore, this preservation of correction is due to an increase in the tone of the foot and lower leg muscles, improvement of proprioception and maturation of connective tissue.

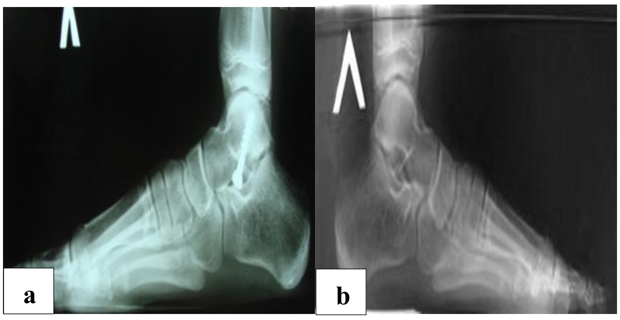

Figure 4: Photoplantograms of patient P (13-year-old) diagnosed with bilateral flexible flatfoot, (a) one year after anterograde calcaneo-stop procedure; and (b) 3 years after removal of cancellous screws.

From the perspective of gender of pediatric population affected with flexible flatfoot, 49 out of 65 (75%) pediatric patients were males and 19 out of 65 (25%) pediatric patients were females; thus, showing a demographic shift to male population. This finding confirms the male gender is one of the predisposing factors for flexible flatfoot in pediatric population.

Many authors have noted the proprioceptive function of implants located 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 is corrected.[10]

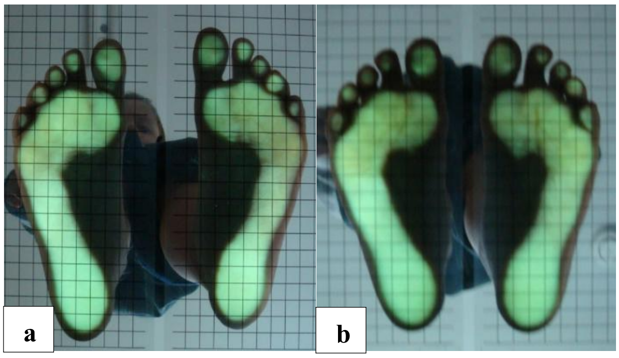

Figure 5: Radiographs of patient P (13-year-old) diagnosed with bilateral flexible flatfoot, (a) 1 year after anterograde calcaneo-stop procedure; and (b) 3 years after removal of cancellous screws.

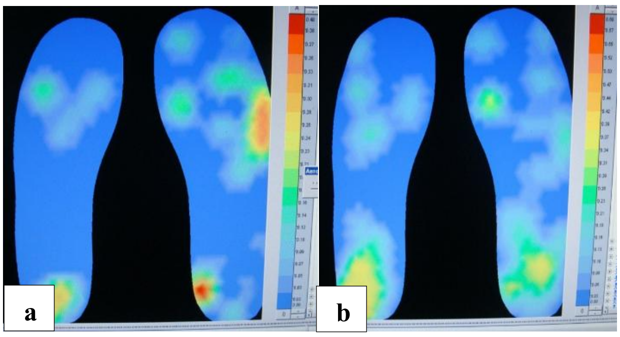

Figure 6: Pedobarograms of patient P (13 years old) diagnosed with bilateral flat feet of III stage, (a) 1 year after anterograde calcaneo-stop procedure; and (b) 3 years after removal of cancellous screws.

Table 1: Changes in radiographic parameters before and 3 years after removal of screws.

Parameter	Before removal	After removal	Statistical significance, p
Talo-I-metatarsal angle	175.5° (172.4/179.8)	174.2° (171.5/180)	0.25
Longitudinal arch angle	142.4±3.3°	143.3±2.3°	0.28
Talar declination angle	25.9±1.5°	26.1±1.7°	0.58
Anteroposterior talocalcaneal angle	23.8° (26.4/19.5)	25.4° (27.7/21.2)	0.33
Lateral talocalcaneal angle	36.5° (49.1/25.0)	36.0° (47.1/24.9)	0.39
Calcaneal inclination angle	13.6° (11.1/16.1)	13.4° (12.2/14.6)	0.11
Talo-II-metatarsal angle	8.9° (2.5/15.3)	10.1° (3.5/16.7)	0.15
Degree of opening of the tarsal sinus, mm	9.9 (6.3/13.5)	9.4 (5.9/12.9)	0.24
Talonavicular coverage angle	8.6° (0/18.3)	8.7° (2.9/21.5)	0.12

Table 2: Changes in photoplantographic parameters before and 3 years after removal of screws.

Parameter	Before removal	After removal	Statistical significance, p
Forefoot print width	83.9 (66.7/96.6)	86.1 (72.8/101.4)	0.07
Midfoot print width	34.6 (29.5/45.7)	41.5 (32.7/48.3)	0.07
Hindfoot print width	44.9 (34.3/59.1)	47.1 (36.6/65.8)	0.08
Outer foot print length	114.7 (102.4/129.8)	116.5 (105.6/134.7)	0.6
Inner foot print length	154.3 (138.5/164.6)	156.8 (142.5/165.3)	0.16
Index Chipaux-Smirak	0.32 (0.24/0.42)	0.34 (0.25/0.46)	0.07
Longitudinal arch index Staheli	0.53 (0.46/0.66)	0.55 (0.47/0.7)	0.11
Clarke angle	43.6° (39.1/48.4)	43.2° (37.4/47.5)	0.06

Table 3: Distribution of pressure on the plantar surface before and 3 years after removal of screws.

Zones of the plantar surface	Pressure before removal, %	Pressure after removal, %	Statistical significance, p
Zone A	18 (15.4/18.1)	18 (16.3/22.5)	0.3
Zone B	32 (25.2/28.4)	31 (26.5/30.3)	0.13
Zone C	1 (4.6/7.5)	2 (1.2/3.2)	0.19
Zone D	18 (17.8/20.2)	18 (18.4/24.2)	0.2
Zone E	31 (31.2/33.4)	31 (32.4/36.1)	0.16

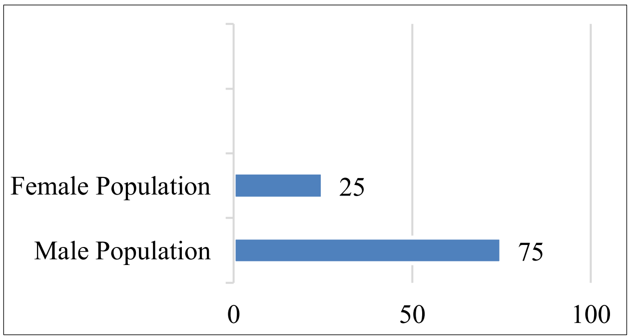

Figure 7: Demographic division of pediatric population affected with flexible flatfoot according to gender.

DISCUSSION

Flatfoot is one of most common foot deformities recorded in the pediatric population. This deformity can be asymptomatic, yet can manifest as pain, difficulty in walking and impairment physically of the skeletal apparatus. The flatfoot is classified into asymptomatic physiologic flatfoot and symptomatic flexible flatfoot. The predisposing factors for flexible flatfoot are male gender, obesity, ligament laxity, neuromuscular abnormalities and genetic or collagen disorders.[12]

The management of flatfoot is categorized into conservative treatments such as application of orthotic shoes, serial exercises and correct positioning of foot during early diagnosis (within the 1st year of life) and surgical interventions. Since conservative therapy is currently not effective in correction after 6 months of its application, surgery is indicated. The anterograde calcaneo-stop method is proven to effective for pediatric population due to its minimally invasive nature and shorter period of recovery.

Furthermore, the use of pedobarographic analysis was useful in determining the outcome of anterograde calcaneo-stop method in flexible flatfoot pediatric patients and surgical influence on the quality of life of the patients.[13] However, some studies have shown use of bioabsorbable calcaneo stop implants has reduced the need for second surgeries to remove the calcaneo-stop implant; but this study was controversial in obese pediatric patients due to the breakage of the implant.[14]

A few publications also reflected on the results of the treatment pediatric flexible flatfoot by anterograde calcaneo-stop method. 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.[15] Kellermann et al concluded that patient satisfaction rate after anterograde calcaneo-stop procedure was excellent for 33 feet of 19 children, good for eight feet of five children, and poor for either foot of one child.[16] DiBello et al concluded that the anterograde calcaneo-stop procedure is a valuable technique, which improves their quality of life and the families' wellbeing.[17] In addition, a systemic review highlighted the efficacy of Calcaneo-stop method in treatment of symptomatic flexible flatfoot in the pediatric population with lesser rate of complications.[18]

Limitations

The following limitations were found in this retrospective study such as incomplete long term follow-up regime (more than 3 years after screw removal) and missing diagnostic data of patients such as X-ray results.

CONCLUSION

The collected data indicated a sufficiently high efficiency of anterograde calcaneo-stop method in the treatment of flexible flatfoot in children. Evaluation of the long-term results revealed improvement in all studied parameters. The analysis of errors and complications indicates the necessity of strict compliance with the technique of surgical intervention, careful preoperative planning. After the removal of screws, there was no recorded loss of the achieved correction.

Recommendations

Early diagnosis of flexible flatfoot in the pediatric population and timely management may improve the quality of life and prognosis of the patients.

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REFERENCES

1. Jordan KP, Kadam UT, Hayward R, Porcheret M, Young C, Croft P. Annual consultation prevalence of regional musculoskeletal problems in primary care: an observational study. BMC Musculoskelet Disord. 2010;11(144):1-10.
2. Harris EJ. The natural history and pathophysiology of flexible flatfoot. Clin Podiatr Med Surg. 2010;27(1):1-23.
3. El O, Akcali O, Kosay C, Kaner B, Arslan Y, Sagol E, et al. Flexible flatfoot and related factors in primary school children: a report of a screening study. Rheumatol Int. 2006;26(11):1050-3.
4. Lee MS, Vanore JV, Thomas JL, Catanzariti AR, Kogler G, Kravitz SR, et al; Clinical Practice Guideline Adult Flatfoot Panel. Diagnosis and treatment of adult flatfoot. J Foot Ankle Surg. 2005;44(2):78-113.
5. Pinney SJ, Lin SS. Current concept review: acquired adult flatfoot deformity. Foot Ankle Int. 2006;27(1):66-75.
6. Jane MacKenzie A, Rome K, Evans AM. The efficacy of nonsurgical interventions for pediatric flexible flat foot: a critical review. J Pediatr Orthop. 2012;32(8):830-4.
7. Wenger DR, Mauldin D, Speck G, Morgan D, Lieber RL. Corrective shoes and inserts as treatment for flexible flatfoot in infants and children. J Bone Joint Surg Am. 1989;71(6):800-10.
8. Whitford D, Esterman A. A randomized controlled trial of two types of in-shoe orthoses in children with flexible excess pronation of the feet. Foot Ankle Int. 2007;28(6):715-23.
9. Staheli LT. Planovalgus foot deformity. Current status. J Am Podiatr Med Assoc. 1999;89(2):94-9.
10. Blitz NM, Stabile RJ, Giorgini RJ, DiDomenico LA. Flexible pediatric and adolescent pes planovalgus: conservative and surgical treatment options. Clin Podiatr Med Surg. 2010;27(1):59-77.
11. Hazany S, Ly N, Hazany D, Bader S, Ostuka N. Outcomes of subtalar arthroereisis for the planovalgus foot. J Surg Orthop Adv. 2012;21(3):147-50.
12. Halabchi F, Mazaheri R, Mirshahi M, Abbasian L. Pediatric flexible flatfoot; clinical aspects and algorithmic approach. Iran J Pediatr. 2013;23(3):247-60.
13. Dibello D, Di Carlo V, Pederiva F. Are Pedobarographic and Gait Analyses Useful Tools to Evaluate Outcomes of Anterograde Calcaneo-Stop Procedure in Pediatric Symptomatic Flexible Flatfoot? Children (Basel). 2022;9(3):366.
14. Giannini S, Cadossi M, Mazzotti A, Persiani V, Tedesco G, Romagnoli M, et al. Bioabsorbable Calcaneo-Stop Implant for the Treatment of Flexible Flatfoot: A Retrospective Cohort Study at a Minimum Follow-Up of 4 Years. J Foot Ankle Surg. 2017;56(4):776-82.
15. Roth S, Sestan B, Tudor A, Ostojic Z, Sasso A, Durbesic A. Minimally invasive calcaneo-stop method for idiopathic, flexible pes planovalgus in children. Foot Ankle Int. 2007;28(9):991-5.
16. Kellermann P, Roth S, Gion K, Boda K, Tóth K. Calcaneo-stop procedure for paediatric flexible flatfoot. Arch Orthop Trauma Surg. 2011;131(10):1363-7.
17. Dibello D, Dallan G, Di Carlo V, Pederiva F. Quality of life in flexible painful flatfoot treated by anterograde calcaneo-stop procedure: The patient's and family's perspective. PLoS One. 2023;18(2):e0263763.
18. Galán-Olleros M, Del Baño Barragán L, Figueroa MJ, Prato de Lima CH, Fraga-Collarte M, Torres-Izquierdo B, 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(7):535-45.

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