ORIGINAL ARTICLE

Preliminary evaluation of the calcaneo-stop technique for flexible flatfoot in children

Avaliação preliminar da técnica calcâneo-stop para pé plano valgo flexível em crianças

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Abstract

Objectives: this study aimed to evaluate the clinical and radiographic outcomes, as well as caregiver satisfaction, in children who underwent the calcaneo-stop procedure. **Methods**: patients aged 11 to 13 years were included in the study. The changes in the American Orthopaedic Foot and Ankle Society (AOFAS) Hindfoot and Ankle Evaluation Scale, reference radiographic angles (Calcaneal Pitch, Kite Angle (AP View), Kite Angle (Lateral View), Meary's Angle, and Giannestras Angle), caregiver satisfaction, and sample characteristics regarding age, sex, and family history were assessed. The pre- and postoperative results were compared. Statistically significant improvement was observed in the AOFAS scale score and favorable radiographic correction. **Results**: the mean age of the cohort was 11.5 years, and a positive family history of flexible flatfoot was identified in 62.5% of cases. Based on the Smith–Millar criterion, surgical outcomes were classified as good in 86.7% of patients and excellent in 13.3%. Postoperative complications were uncommon, with 93.3% of patients remaining complication-free. Significant functional improvement was observed, demonstrated by increased AOFAS scores, enhanced foot function, and radiographic correction of the Kite, Meary, Giannestras, and Calcaneal Pitch angles. **Conclusion**: the calcaneo-stop technique demonstrated safety and efficacy, providing significant clinical and radiographic improvement and yielding high levels of caregiver satisfaction.

Keywords: flatfoot; orthopedic procedures; evaluation of results of therapeutic interventions; health profile.

Resumo

Objetivos: avaliar os desfechos clínicos e radiográficos, bem como o grau de satisfação dos cuidadores, em crianças submetidas ao procedimento de calcâneo-stop. **Métodos**: Foram incluídos pacientes entre 11 e 13 anos de idade. Foram analisadas as variações na escala de avaliação do retropé e tornozelo da American Orthopaedic Foot and Ankle Society (AOFAS), os principais ângulos radiográficos de referência (Ângulo de Inclinação do Calcâneo, Ângulo de Kite nas incidências anteroposterior e lateral, Ângulo de Meary e Ângulo de Giannestras), além da satisfação dos cuidadores e características da amostra quanto à idade, sexo e histórico familiar. Os resultados pré e pós-operatórios foram comparados, observando-se melhora estatisticamente significativa na pontuação da escala AOFAS e correção radiográfica favorável. **Resultados**: A média de idade dos pacientes foi de 11,5 anos, e histórico familiar positivo para pé plano flexível foi identificado em 62,5% dos casos. De acordo com o critério de Smith–Millar, os resultados cirúrgicos foram classificados como bons em 86,7% dos pacientes e excelentes em 13,3%. As complicações pós-operatórias foram incomuns, com 93,3% dos pacientes sem intercorrências. Observou-se melhora funcional significativa, evidenciada pelo aumento das pontuações da escala AOFAS, melhor desempenho funcional dos pés e correção radiográfica dos ângulos de Kite, Meary, Giannestras e Inclinação do Calcâneo. **Conclusão**: A técnica de calcâneo-stop demonstrou, mais uma vez, ser segura e eficaz, promovendo melhora clínica e radiográfica significativa, além de altos índices de satisfação entre os cuidadores.

Palavras-chave: Pé Chato; Procedimentos Ortopédicos; Avaliação de Resultado de Intervenções Terapêuticas; Perfil de Saúde.

INTRODUCTION

Flat valgus foot is the term used to describe the reduction or absence of the longitudinal arch of the foot and hindfoot valgus[1]. Among the risk factors described in the literature, male sex, higher body mass index, and shorter stature stand out[2]. The deformity can be rigid or flexible depending on the mobility of the tarsus and subtalar joints. In the flexible form, the arch is normal without a load and is lowered under a weight; this may be associated with symptoms[1]. In this case, the longitudinal arch reappears when the patient stands on the toes or with the ankle in plantar flexion[1]. In the absence of symptoms, flexible flatfoot represents only an anatomical variation; however, its persistence beyond the age of 10 years may be clinically relevant[3]. Pain symptoms may develop due to multifactorial influences[4]. Pain can manifest in the medial or lateral regions of the foot, with the former being more frequent and resulting from localized pressure on the collapsed talar head, often accompanied by calluses[4]. The impact of this condition on daily life includes limitations in tasks, constant muscle fatigue, and expenses owing to rapid shoe wear[4]. The propensity for recurrent ankle sprains increases the risk of injury and compromises stability, potentially resulting in progressive deformity[4]. Treatment of symptomatic flexible flatfoot begins

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with conservative measures, failure of which is the primary surgical indication[5]. In this context, subtalar arthroereisis is a minimally invasive procedure that restricts excessive eversion of the subtalar joint through implants[5]. This intervention aims to limit the valgus of the subtalar joint and improve hindfoot alignment, contributing to the restoration of the medial arch of the foot[5].

The calcaneo-stop (C-Stop) is a percutaneous arthroereisis technique that uses a screw in the sinus tarsi and is a low-cost technique with results comparable to those of other procedures[6]. The surgical technique is performed with the patient in the supine position. The procedure begins with an incision of approximately 1 to 2 cm on the lateral aspect of the foot, above the sinus tarsi. After identifying the fascia and the capsule surrounding the sinus tarsi, an incision is made to access this space[3]. A guide wire is then inserted perpendicularly towards the medial malleolus direction until reaching the plantar cortex of the calcaneus, ensuring proper alignment between the talus and calcaneus[7]. Subsequently, a screw is placed to prevent valgus displacement of the calcaneus in relation to the talus, thereby limiting excessive subtalar pronation and promoting mechanical stability of the hindfoot. Following correction, intraoperative radiographic assessment is performed to confirm adequate positioning and maintenance of the restored talocalcaneal relationship[3,7]. The result is immediate, with visible correction of the deformity and the medial and lateral malleoli of the foot should be clearly identifiable, reflecting the characteristic postoperative alignmentn[7]. Finally, layered closure is performed. The result should be immediate, and the medial and lateral malleoli of the foot should be visible[3,7]. This technique is mainly indicated for children and adolescents between 8 and 14 years of age, as it shows a higher failure rate in adults[8].

Long-term evidence reinforces the safety and low morbidity of the C-stop procedure, as in an Italian cohort of 400 patients, in which 96.8% had good outcomes[9]. In young athletes, satisfactory rehabilitation and early return to sports within one year were observed, including in individuals with high physical demand[9], reinforcing the relevance of disseminating the technique in the pediatric population. Despite the growing evidence supporting this procedure, reports from small institutional series remain valuable to document early outcomes and contribute to clinical practice. Considering the findings in the literature and the clinical relevance of the topic, the primary objective of the present study is the initial clinical evaluation of the feet of patients who underwent the C-Stop procedure using the American Orthopaedic Foot and Ankle Society (AOFAS) Hindfoot and Ankle Rating Scale. Secondary objectives included assessing changes in the reference radiographic angles for the ankle, measuring the level of caregiver satisfaction after the procedure, and characterizing the sample regarding the mean age, sex, and family history of patients undergoing surgery.

METHODS

Participants

Patients aged <15 years (skeletally immature) with a diagnosis of symptomatic flexible flat valgus foot, treated at the Ortoclínica de Sergipe (CEOT Clinic) in Aracaju-SE, who underwent surgical arthroereisis using the C-Stop technique between January 2021 and June 2023, were evaluated. Inclusion criteria were: having been treated by the pediatric orthopedics team at CEOT Clinic; age ≤ 15 years; diagnosis of flexible flat valgus foot; having undergone surgical arthroereisis using the C-Stop technique; agreeing to participate and signing the informed consent form (ICF) and the assent form. Patients whose data were presented with incomplete and/or missing information and those who did not undergo imaging examinations were excluded.

Instruments

Hindfoot and Ankle Evaluation Scale of the American Orthopaedic Foot and Ankle Society [10] Composed of nine sections divided into three categories: pain (0–40 points), functional aspect (0–50 points), and alignment (0–10 points). The final score was calculated by summing the items and ranged from 0 to 100 points. This result is proportional to the best functional capacity. The scale was translated into Brazilian Portuguese and validated by Rodrigues et al. (2008)[11] to assess clinical conditions of the ankle and foot.

Satisfaction Scale

Caregiver satisfaction was assessed using a Likert-type questionnaire specifically developed by the authors for this study. The instrument included eight items addressing perceived improvement in foot curvature, range of motion, pain reduction (medial, lateral, and ankle regions), joint stability, functional mobility, and fatigue in daily activities, as well as postoperative complications.

Each item was assigned a score ranging from 0 to 5, and the total score was calculated as the sum of all items. This scale assessed the degree of agreement or disagreement among respondents regarding a series of statements associated with the outcomes of the surgical procedure.

The questionnaire was designed to capture satisfaction domains directly related to the outcomes of the C-stop procedure, since no validated tool for this specific context is available in the literature.

Sociodemographic Questionnaire

The data were related to sex (male, female, and non-binary), age (years), and city of residence.

Procedures and Ethical Aspects

This study used a retrospective longitudinal observational design, based on a purposive convenience sampling method. It represents an institutional experience with the C-stop technique. Data were collected from the database of an orthopedic clinic in Aracaju, SE, using electronic medical records. The participants were contacted via phone calls and social media (WhatsApp and Email). For clinical evaluation, confirmation of the Assent Form (TALE) for caregivers and the Informed Consent Form (TCLE) for adolescents was mandatory. This study was approved by the National Research Ethics Committee (CONEP), under CAAE No. 71602723.7.0000.5371, and was conducted in accordance with the ethical principles established by the Declaration of Helsinki. Ethical considerations established by research guidelines involving human subjects were duly observed.

Data Analysis

The exploratory data analysis was performed with the calculation of simple frequency and percentage for the sociodemographic variables, Smith-Millar scale, and treatment descriptor variables. The mean, standard deviation, and minimum and maximum values were calculated for age, variables related to caregiver satisfaction, and screw size. The comparison between preoperative and postoperative was performed based on the AOFAS scale and radiological findings. Results were expressed as median ± interquartile range (I.I.R.), and statistical comparison was performed using the Wilcoxon test (1945)[12]. The data were organized in Microsoft Excel, and all statistical analyses were performed using R software[13], version 4.4.3. The significance level adopted was 5%.

RESULTS

The sample consisted of eight children equally distributed between the female and male sexes, and all residents of Aracaju, SE. A total of 15 feet were analyzed, of which 7 patients underwent bilateral surgery and 1 patient underwent surgery on a single foot. Most children (62.5%) had a family history of the condition. The most frequently affected relatives were parents (40.0%), grandparents (20.0%), uncles/aunts (20.0%), and a combination of parents and uncles/aunts (20.0%). Screws with diameters of 4.5 mm (n = 13) and 7.0 mm (n = 2) were used for fixation. One patient underwent the Hoke procedure on both feet in association with flatfoot corrective surgery. Regarding the evaluation of the surgical outcome according to the Smith-Millar criterion, most patients (86.7%) achieved a result considered "good," while 13.3% were classified as having an "excellent" result. Most children (93.3%) did not present with complications, while only one developed a complication characterized as pain at the screw insertion site. The condition was managed with local corticosteroid infiltration, which resulted in symptom improvement.

Table 1 describes the quantitative variables used in this study. The mean patient age was 11.5 years. Post-surgical complications were minimal. Table 2 presents caregiver satisfaction results, showing scores close to the maximum for perceived improvement in the longitudinal arch, range of motion, pain reduction, and joint dynamics.

Table 1. Quantitative variables analyzed in the study.

Variable	n	Mean	S.D.	Min.	Max.
Age	8	11,5	0,8	11,0	13,0
Increase in the curvature of the longitudinal arch of the foot	8	4,9	0,4	4,0	5,0
Improvement in range of motion	8	4,9	0,4	4,0	5,0
Reduction of pain in the medial region of the foot	8	5,0	0,0	5,0	5,0
Reduction of pain in the lateral region of the foot	8	4,9	0,4	4,0	5,0
Reduction of pain or instability in the ankle joint	8	5,0	0,0	5,0	5,0
Improvement in joint movement dynamics	8	5,0	0,0	5,0	5,0
Reduction of fatigue in daily tasks	8	5,0	0,0	5,0	5,0
Post-surgical complication	8	1,0	0,0	1,0	1,0
Overall satisfaction	8	5,0	0,1	4,8	5,0

Legend: Description and measurement details of the quantitative variables considered in this study. S.D. = Standard Deviation; Min. = Minimum; Max. = Maximum.

Table 2. Caregiver satisfaction outcomes after the calcaneo-stop procedure.

Variable	Mean +- SD	Median	Min - Max
Perceived increase in longitudinal arch	4,88 ± 0,35	5,0	4 - 5
Improvement in range of motion	4,88 ± 0,35	5,0	4 - 5
Reduction of medial foot pain	5,00 ± 0,00	5,0	5 - 5
Reduction of lateral foot pain	4,88 ± 0,35	5,0	4 - 5
Reduction of ankle pain/instability	5,00 ± 0,00	5,0	5 - 5
Improvement in joint motion dynamics	5,00 ± 0,00	5,0	5 - 5
Reduction of fatigue in daily activities	5,00 ± 0,00	5,0	5 - 5
Presence of complications	0,00 ± 0,00	0,00	0 - 0

Legend: Summary of responses from the caregiver satisfaction questionnaire developed for this study to evaluate perceived postoperative improvement. S.D. = Standard Deviation, Min. = Minimum; Max. = Maximum.

Table 3 presents the preoperative and postoperative comparisons of the evaluated variables, including the AOFAS scale and radiographic parameters. A significant improvement in foot function was observed with an increase in the AOFAS score and correction of the radiographic angles (p = 0.001 for all measures). Figures 1 and 2 illustrate the clinical and radiographic aspects, respectively, of one of the evaluated patients before and after the procedure.

Table 3. Preoperative and postoperative comparison clinical and radiographic variables

Variable	Preoperative (Mean +- SD)	Postoperative (Mean +-SD)	P-value
AOFAS	49,0 ± 25,5	100,0 ± 8,5	0,001
Calcaneal Pitch	10,0 ± 8,0	18,0 ± 7,0	0,001
Kite Angle (AP View)	34,0 ± 3,0	22,0 ± 6,0	0,001
Kite Angle (Lateral View)	38,0 ± 2,0	30,0 ± 3,0	0,001
Meary's Angle	-18,0 ± 5,0	-8,0 ± 4,0	0,001
Giannestras Angle	34,0 ± 10,0	56,0 ± 5,0	0,001

Legend: Comparison of clinical and radiographic parameters evaluated before and after the calcaneo-stop procedure. S.D. = Standard Deviation.

Figure 1. Faro, L. et al. Clinical aspect of a male patient submitted to the C-Stop procedure for flat valgus foot. (A, B) Preoperative records in 2022. (C, D) Postoperative records in 2024.

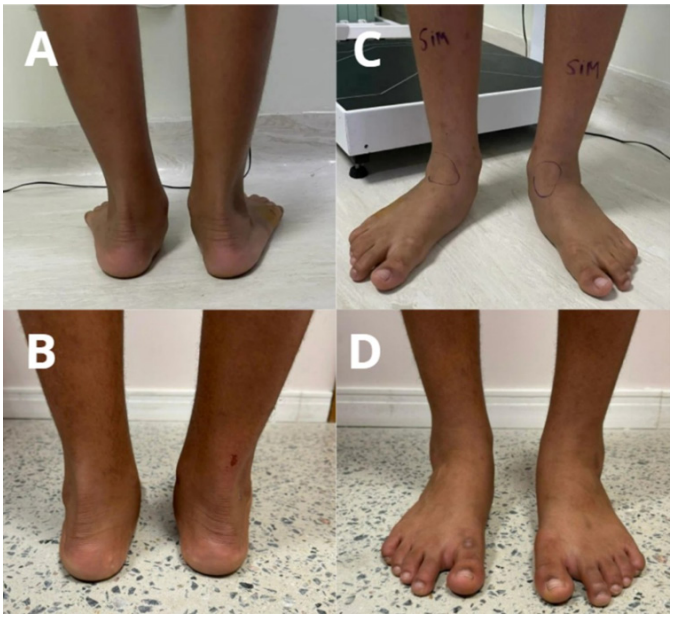
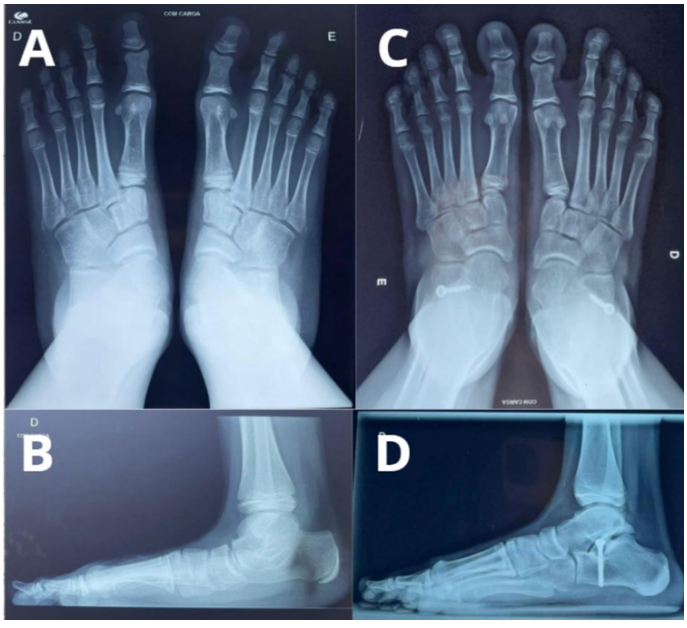


Figure 2. Faro, L. et al. Radiographic aspect of a male patient submitted to the C-Stop procedure for flat valgus foot. (A, B) Preoperative records in 2022. (C, D) Postoperative records in 2024.



DISCUSSION

The clinical improvement observed in the AOFAS score is consistent with the literature, in which the arthroereisis technique demonstrated significant functional progress with a positive impact on pain, daily activities, and hindfoot function. In a randomized clinical trial with 66 pediatric patients, subtalar arthrodesis increased the AOFAS score from 68.71 ± 5.70 to 87.87 ± 7.14 ($p < 0.001$)[14]. Similar results were reported in another study with 81 children, which showed a significant increase in all components of the AOFAS score[15].

The radiographic parameters showed favorable progression at all angles evaluated, corroborating studies reporting adequate hindfoot correction after the intervention. A recent meta-analysis involving approximately 2,400 feet submitted to the C-Stop technique identified significant improvements in the Kite (7.32°), Meary (11.65°), and Calcaneal Pitch (5.92°) angles[1]. In the present study, greater improvements were observed in the Kite AP View (12°) and Calcaneal Pitch (8°) angles. Similar results regarding the radiographic benefits of C-Stop have been reported in the literature[6 ,16, 17]. As found in this study, other studies have reported a low complication rate, with pain at the surgical site being the most common and managed conservatively[1,7,13]. These findings indicate that the C-Stop technique promotes significant improvements in the bony architecture of the foot with low morbidity.

In this study, the surgical procedure was performed in patients aged 11–13 years, with a balanced distribution between the sexes. In the literature, younger age and male sex are risk factors for flat valgus foot, as demonstrated by a systematic review and meta-analysis of 3,602 children in which the age ranges of 6–9 years and < 9 years were predominantly boys[18]. A positive family history proved to be a relevant factor within the study population, in agreement with the literature that highlights that frequent occurrences in relatives motivate the evaluation of other family members during clinical care[19]. Caregivers' satisfaction responses were broadly positive, reflecting the correspondence between the objective results and subjective clinical perceptions. Previous studies with pediatric patients submitted to the C-Stop corroborate these findings: a 2024 systematic review and meta-analysis revealed "high satisfaction" in 94.8% of cases, with a complication rate of 7.8% in 2,394 feet from 1,415 patients[1]. A longitudinal study of 12 patients also reported significant satisfaction in 91.6% of the patients16, reinforcing the clinical relevance of the procedure and the need for future investigations with larger samples and longer follow-up periods.

In one case, Achilles tendon lengthening was performed using the Hoke technique due to mechanical indication. The procedure was indicated because the patient exhibited adaptive shortening of the Achilles tendon. In flexible flatfoot, the pronated and everted position of the foot alters the alignment of the Achilles tendon, causing it to act asymmetrically and leading to progressive adaptive shortening and equinus deformity[7].

High levels of caregiver satisfaction were observed across all evaluated domains (Table 2). The mean scores ranged from 4.88 to 5.0 on the Likert scale, with low variability (SD ≤ 0.35), indicating consistent and favorable perceptions among respondents. Caregivers reported noticeable improvement in the longitudinal arch, range of motion, pain reduction, and joint dynamics. Similar findings of high parental satisfaction have been described after the C-stop procedure in other orthopedic series[7]. Although several generic instruments exist to assess parental satisfaction in pediatric orthopedic settings, no validated scale is available specifically for this procedure or clinical population; therefore, satisfaction was assessed descriptively in accordance with prior studies. No postoperative complications were reported, further reinforcing the overall positive outcomes associated with the C-stop procedure.

Although the results are favorable, the small number of patients and the fact that the study was conducted in a single clinic limit generalizability, making multicenter studies with longer follow-ups necessary to assess the success factors and potential long-term complications. Another limitation is that the caregiver satisfaction questionnaire was developed by the authors and has not undergone formal psychometric validation. However, it was specifically designed to assess domains relevant to the C-stop procedure, for which no standardized or validated instrument currently exists. Despite these limitations, this study provides valuable insights from our institutional experience, reinforcing the feasibility and safety of the C-stop technique in the pediatric population. While the C-stop technique is well established in the literature, the present study contributes by demonstrating its practical applicability and consistent outcomes in the authors' experience.

CONCLUSION

The C-Stop technique has been proven to be effective and safe for the treatment of flexible flatfoot in skeletally immature patients. Clinical and radiographic improvements, as well as high satisfaction rates, were observed even in the medium term. Most patients had a positive family history, mainly involving their parents. These findings support the indications for this procedure in symptomatic patients who are refractory to conservative treatment. Thus, the C-Stop technique presents low morbidity and low cost and is suitable for children with flat valgus foot.

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