DOI: https://doi.org/10.30795/scijfootankle.2019.v13.915

ORIGINAL ARTICLE

Scientific Journal of the Foot & Ankle

Correction of pediatric flexible flatfoot using arthroereisis

Correção de pé plano valgo flexível pediátrico por artrorrise

Leandro Paes de Brito[1], Cíntia Kelly Bittar[1], Mário Sérgio Paulillo de Cillo[1], Carlos Daniel Candido de Castro Filho[1], Renê André Reinig Carvalho[1], Maria Augusta Back do Nascimento[1]

1. Pontifícia Universidade Católica de Campinas, Campinas, SP, Brazil.

ABSTRACT

Objective: The aim of this study was to evaluate the effectiveness of arthroereisis using synthetic polyethylene implants as a method to correct deformities of excessive valgus in pediatric patients with flexible flatfoot (FF).

Methods: This was a study of 20 patients between 5 and 12 years of age with symptomatic FF who received surgery between January 2011 and July 2016. Evaluations were made on the basis of the Valenti podoscopic classification, radiographic images, and AOFAS criteria. Patients with preoperative Valenti classification grades of III and IV were selected for the study. These patients received surgical treatment by arthroereisis with the interposition of a synthetic implant in the sinus tarsi, with or without stretching of the Achilles tendon (Vulpius surgery). A multiple linear regression analysis was performed with backward selection of the following variables: Valenti preoperative classification and the pre- and postoperative Bordelon, Kite, Gould, Meary and Pitch angles that were measured from the radiographic images of the patients who received arthroereisis.

Results: Arthroereisis with synthetic material interposition was satisfactory, with 21 of the feet (91% of cases) showing clinical and radiographic improvement with angle correction and improved degree of deformity based on the Valenti classification. Two cases experienced implant loosening. The Bordelon and Pitch angle variables had a significant effect ($p<0.05$) on the improvement in degree of deformity correction based on the Valenti classification.

Conclusion: Arthroereisis resulted in significant improvements in the patients who were studied, with pronounced clinical improvement and high degrees of satisfaction.

Level of evidence IV; Therapeutic Studies; Case Series.

Keywords: Flatfoot/surgery; Prostheses and implants; Orthopedic procedures; Heel.

RESUMO

Objetivo: Avaliar a efetividade da artrorrise com a utilização de implante sintético de polietileno, como método de correção da deformidade em valgo excessivo em pacientes pediátricos com pé plano flexível.

Métodos: Estudo de 20 pacientes com PPVF sintomático entre 5 e 12 anos de operados, entre janeiro de 2011 a julho de 2016. Foram realizadas avaliações clínicas com base na classificação podoscópica segundo Valenti, nas imagens radiográficas e nos critérios AOFAS. Foram selecionados os pacientes que obtiveram graus III e IV pré-operatório, segundo classificação de Valenti. Esses pacientes foram submetidos a tratamento cirúrgico por artrorrise com a interposição de implante sintético no seio do tarso, associado ou não ao alongamento do tendão de Aquiles (cirurgia de Vulpius). Foi realizada a análise de regressão linear múltipla com seleção Backward das variáveis, classificação de Valenti pré-operatória, os ângulos de Bordelon, Kite, Gould, Meary e de Pitch dos pré e pós-operatórios das imagens radiográficas dos pacientes submetidos à artrorisse.

Resultados: A artrorrise com interposição de material sintético, mostrou-se satisfatória, tendo em vista que 21 dos pés (91% dos casos) apresentaram melhora clínica e radiográfica, com correção dos ângulos e melhora nos graus de deformidade com base na classificação de Valenti. Dois casos apresentaram soltura do implante. As variáveis dos ângulos de Bordelon e Pitch influenciaram significativamente ($p<0,05$) na melhora da correção dos graus de deformidade com base na classificação de Valenti.

Work performed at the Pontifícia Universidade Católica de Campinas, Campinas, SP, Brazil.

Correspondence: Cíntia Kelly Bittar. Av. John Boyd Dunlop, S/N - Jardim Londres, Campinas, SP, Brazil, CEP: 13034-685. E-mail: ckbitt@gmail.com
Conflicts of interest: none. **Source of funding:** none.
Date received: December 28, 2018. **Date accepted:** April 22, 2019. **Online:** May 31, 2019.

Conclusão: A artrorrise demostrou resultados significativos nos pacientes estudados, com importante melhora clínica e alto grau de satisfação. ***Nível de Evidência IV; Estudos Terapêuticos; Série de Casos.***

Descritores: Pé plano/cirurgia; Implantes artificiais; Procedimentos ortopédicos; Seio do tarso.

How to cite this article: Brito LP, Bittar CK, Cillo MSP, Castro Filho CDC, Carvalho RAR, Nascimento MAB. Correction of pediatric flexible flatfoot using arthroereisis. Sci J Foot Ankle. 2019;13(2):112-8.

INTRODUCTION

Flexible flatfoot (FF) is one of the most common orthopedic pathologies in children[1]. Most of these patients do not present any symptoms and report only diffuse and poorly located pain when walking long distances and during physical activity. This pain may be in the foot but can also extend to the ankle or leg[2].

The most obvious changes in patients with FF include loss of the medial longitudinal arch, plantar flexion of the talus relative to the calcaneus, plantar medial prominence of the talar head, forefoot abduction in the talonavicular joint and calcaneal valgus[3]. It is believed that pediatric patients who receive no treatment can also develop secondary deformities, such as postural disorders[4].

Surgical indication in FF cases is a topic that is still under much discussion[5], especially regarding the ideal age that pediatric patients could receive surgery. Some authors report that the surgery should be performed in patients between 8 and 14 years of age[6-9]. However, there is substantial variation in the age at which children are recommended for the surgery and can include patients of 2 to 6 years of age[10].

Arthroereisis is one of the most commonly used procedures in Europe for FF correction in pediatric patients[7,9,11]. This procedure is so common because it is a minimally invasive alternative[9] compared with the other surgical procedures such as tendon stretching and transfer, bone excision, osteotomy, arthrodesis, and bone or synthetic material interposition in the sinus tarsi.

In light of the above and considering the cases of surgical indication in pediatric patients with FF who are refractory to conservative treatment, the aim of this study was to evaluate the effectiveness of arthroereisis using synthetic polyethylene implants as the deformity correction method of excessive valgus in pediatric patients with flexible flatfoot.

METHODS

This study was approved by the Research Ethics Committee with registration in the Brazil Platform under CAAE number: 90459018.0.0000.5599.

Twenty patients (23 feet) with symptomatic FF between 5 and 12 years of age at the time of surgery were studied, with a mean 33 months of follow-up, ranging from 24 to 43 months. The patients' symptomology included foot pain during daily activities, during or after sports or early muscle fatigue during impact sports activities that placed a significant burden on the foot.

The selected patients first received conservative treatment for six months[12,13], with the use of insoles, nonsteroidal anti-inflammatory drugs and/or physiotherapy treatment for stretching and strengthening the extrinsic and intrinsic foot musculature. Patients with a satisfactory response to this conservative treatment were excluded from the study.

The clinical evaluation criteria used in this study was the Valenti podoscopic classification, which is designed to measure different degrees of deformity, as follows: grade I (midfoot width exceeding 1/3 of forefoot width); grade II (midfoot width more than 1/2 of forefoot width); grade III (midfoot width exceeding forefoot width); and grade IV (bulging of medial edge - semilunate image).

The radiographic images in the anteroposterior incidence (AP) revealed the talonavicular (Bordelon), talocalcaneal (Kite), and Gould angles and revealed the talus - first metatarsal (Meary) and heel inclination (calcaneal pitch) angles in profile. All of the angle measurements were performed while the patient was bearing weight (Table 1).

The patients were also evaluated using the *American Orthopedic Foot and Ankle Society* (AOFAS)[14] criteria on the ankle and hindfoot scale. Applying this questionnaire allowed us to analyze the data regarding pain, limitation of activities, need for support, stride length and abnormalities, sagittal and hindfoot mobility, ankle stability, and stability of the hindfoot and its alignment, as well as degree of satisfaction and complications.

After analyzing the clinical evaluation criteria, patients who were refractory to conservative treatment with Valenti podoscopic classification grades of III and IV with persistent painful symptomatology received surgical treatment by arthroereisis with a synthetic implant interposition (tapered polyethylene screw) in the sinus tarsi,

Table 1. Evolution of the radiological parameters, Valenti podological classification, AOFAS criteria, and pre- and postsurgical procedure for flexible flatfoot correction by arthroereisis in pediatric patients between 5 and 12 years of age.

	Age	Sex	Bordelon angle	Kite angle	Gould angle	Meary angle	Pitch angle	Valenti classification	AOFAS criteria
			Pre/post surg.	Pre/post surg.	Pre/post surg.	Pre/post surg.	Pre/post surg.	Pre/post surg.	Pre/post surg.
Pé 1	7	M	17-18°	48-51°	8-8mm	21-24°	12-12°	Grade IV-IV	69-80
Pé 2	12	M	20-12°	43-35°	8-5mm	18-11°	10-16°	Grade IV-II	70-97
Pé 3	8	F	19-15°	50-41°	7-6 mm	22-17°	8-12°	Grade III-II	70-94
Pé 4	8	F	22-18°	54-49°	9-7 mm	25-19°	8-13°	Grade IV-II	73-97
Pé 5	6	M	28-18°	58-46°	9-5 mm	26-17°	9-16°	Grade IV-III	70-95
Pé 6	5	F	20-15°	55-40°	7-4 mm	17-10°	10-18°	Grade III-II	78-92
Pé 7	7	M	22-13°	61-41°	7-5 mm	20-14°	9-17°	Grade IV-II	75-96
Pé 8	10	M	28-20°	62-40°	7-4 mm	27-17°	7-13°	Grade IV-II	71-97
Pé 9	8	F	17-12°	42-38°	6-5 mm	18-15°	10-14°	Grade III-I	76-97
Pé 10	9	M	23-16°	56-41°	8-5 mm	19-14°	12-19°	Grade IV-III	74-89
Pé 11	6	M	23-14°	50-41°	7-5 mm	26-14°	8-14°	Grade IV-II	73-95
Pé 12	8	F	28-20°	55-42°	8-5 mm	28-16°	7-18°	Grade IV-III	75-88
Pé 13	7	F	30-16°	47-39°	7-5 mm	31-16°	10-19°	Grade IV-III	70-87
Pé 14	8	F	32-18°	50-41°	7-6 mm	28-18°	9-16°	Grade IV-II	72-98
Pé 15	9	M	27-15°	49-38°	8-6 mm	31-18°	11-18°	Grade IV-II	74-97
Pé 16	9	M	26-16°	53-41°	8-7 mm	29-20°	10-18°	Grade IV-II	75-97
Pé 17	7	M	30-19°	50-43°	7-6 mm	27-21°	9-16°	Grade IV-II	67-99
Pé 18	6	F	28-18°	58-46°	9-5 mm	26-17°	9-16°	Grade IV-III	78-90
Pé 19	10	M	20-15°	55-40°	7-4 mm	17-10°	10-18°	Grade III-II	74-90
Pé 20	12	M	16-18°	47-52°	7-7 mm	22-24°	11-11°	Grade IV-IV	68-79
Pé 21	9	F	20-12°	43-35°	8-5 mm	18-11°	10-16°	Grade IV-II	70-93
Pé 22	8	F	19-15°	50-41°	7-6 mm	22-17°	8-12°	Grade III-II	73-93
Pé 23	8	F	22-18°	54-49°	9-7 mm	25-19°	8-13°	Grade IV-II	74-90

Pre/post surg. = Pre- and postsurgery.
Source: Prepared by the author based on the results of the research.

with or without stretching of the Achilles tendon (Vulpius surgery) (Figure 1) between January 2011 and July 2016.

For the surgical procedure, the patient was placed in a supine position with a tourniquet placed on the thigh, and the majority of patients were placed under spinal anesthesia and in some cases general anesthesia. An incision was made over the sinus tarsi parallel to the Langer skin lines (Figure 2), with dissection by planes, partial release of the proximal insertion of the short extensor digitorum muscle, and exposure of the upper calcaneal surface. A guide wire was inserted through the sinus tarsi, approximately 15º-20º from perpendicular to the sagittal plane, in the anterolateral to postero-medial direction and exiting below the posterior tibial tendon (Figure 3). The test implant was inserted into the guide wire and an initial assessment was performed to verify calcaneal eversion. The proper insertion distance was confirmed by fluoroscopic view. The lateral edge of the implant was located medial to the lateral side of the talus, and the guide wire was then removed. When necessary, the tendons of the triceps surae muscles were stretched.

A multiple linear regression analysis with backward selection was used on the variables that were analyzed by the Valenti podoscopic classification to verify the predictive power of the response variable, i.e., the efficiency of arthroereisis in improving the degree of deformity in FF patients. The statistical analyses were performed with R Core Team Software (2017)[15].

RESULTS

The results of the clinical evaluation indicate that arthroereisis with synthetic material interposition proved satisfactory according to the Valenti podoscopic classification. Twenty-one feet (91.3%) showed an improvement in the degree of valgus deformity, and two feet (8.7%) remained unchanged (Table 1). During the intraoperative period, improvements were observed in the medial plantar

arch (Figure 4) and in the correction of the hindfoot valgus (Figure 5).

The Bordelon, Kite, and Meary angles decreased on average by 6.75°, 10.5°, and 7.5°, respectively. The calcaneal pitch increased by an average of 6.7° (Figure 6), and talonavicular coverage (Gould) increased by 1.9 mm. The average correction was 7º for calcaneal pitch, 1 and 2 mm for Gould, 9º for the Bordelon and Kite angles and 9° and 6º for the Meary angle (Table 1).

The average AOFAS questionnaire results[14] were 73 points preoperatively and 92 points postoperatively (Table 1). The interview was conducted with patients and their families and had an average duration of 10 minutes. The interview in the postoperative period was performed after an average follow-up period of 33 months. The patients' and family members' satisfaction index was positive, and only 8.7% of the patients were dissatisfied.

The main postoperative complication that was observed was the loosening of the implant, which occurred in two feet and which led to the need for a new surgical procedure for implant removal. In such cases, the Bordelon, Kite,

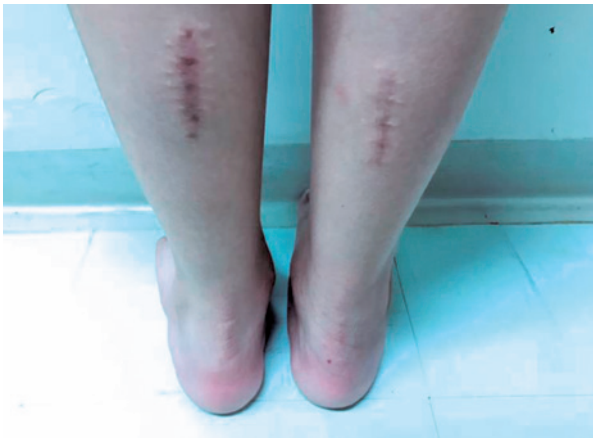

Figure 1. Pediatric patient with FF undergoing arthroereisis with interposition of a synthetic polyethylene implant that was associated with the extension of the Achilles tendon (Vulpius surgery).
Source: Author's personal archive.

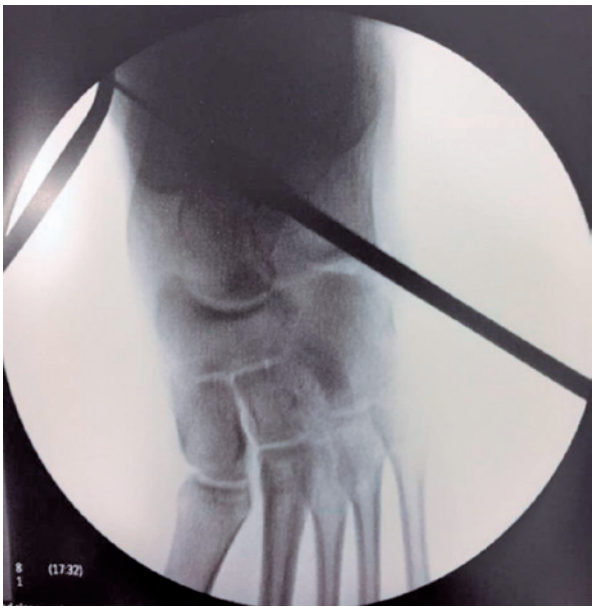

Figure 3. Insertion of the guide wire through the sinus tarsi.
Source: Author's personal archive.

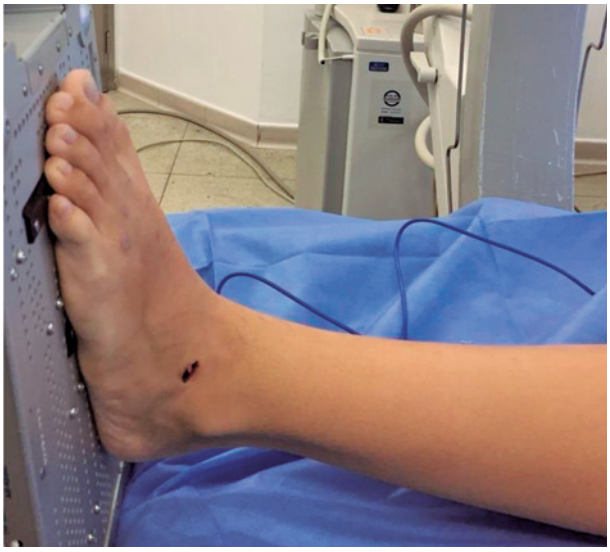

Figure 2. Incision into the sinus tarsi.
Source: Author's personal archive.

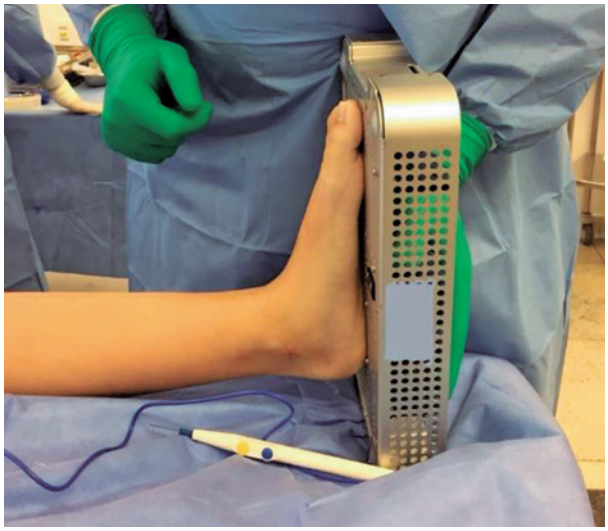

Figure 4. The intraoperative improvement in the medial plantar arch.
Source: Author's personal archive.

and Meary angles were not corrected, and the Gould and Pitch angles and degree of deformity according to Valenti classification (Grade IV) remained unchanged (Table 1).

According to the backward regression model, the Bordelon and Pitch angle variables had a significant effect (p <0.05) on improving the degree of deformity correction based on the Valenti classification. The obtained model correlated to the value of 64%, demonstrating the relationship between the variables.

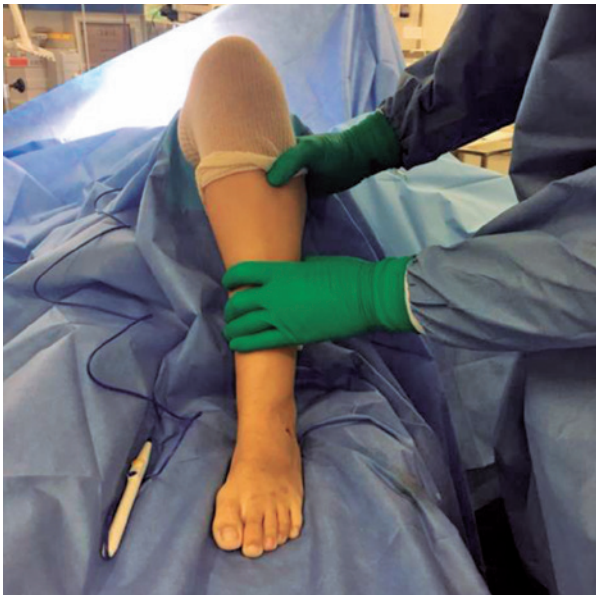

Figure 5. The intraoperative correction of the hindfoot valgus.
Source: Author's personal archive.

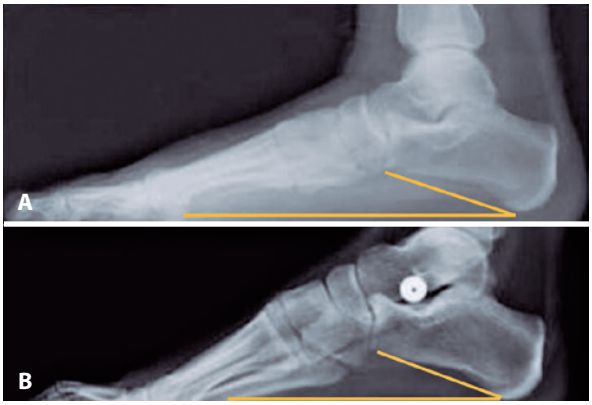

Figure 6. (A) Pre- and (B) postoperative radiographic images of a pediatric patient with FF who received arthroereisis with polyethylene synthetic material implantation and showed a satisfactory response to the surgical procedure.
Source: Author's personal archive.

DISCUSSION

This study's selection criteria for patients with regard to age[16] was consistent with that found in the literature. There is a substantial variation in patient ages between studies, with some including children as young as 2-6 years old[10]. Arthroereisis in patients in this age group who have persistent pain symptoms after conservative treatment has demonstrated a lower incidence of coalition and likely positive results[10].

Although surgical indication for FF is still a widely discussed topic, the literature does not describe the factors that would mitigate against performing the procedure on patients under 8 years of age, despite the number of positive results that have been seen from this procedure. The foremost consideration in these cases should be the patient's quality of life. The indications for the procedure should include the conjunction of symptoms, especially persistent pain symptoms, morphological criteria, and the failure of well-conducted conservative treatment that was at least 6 months in duration[12,13].

Only one five-year-old and three six-year-old patients were included in this study. These patients were grades III and IV and were included after conservative treatment had produced no significant improvement in their painful symptomatology. The results of the arthroereisis procedure in these cases were considered satisfactory, with regards to both the improvement in the degree of deformity according to the Valenti podoscopic classification and in terms of patient and family satisfaction based on AOFAS criteria.

It was possible to observe excellent results with respect to the polyethylene implants that were used, since only two cases (8.69%) failed to achieve satisfactory results. In those cases, the implants that were placed for FF correction loosened, and the patients complained of pain after surgery. The implant therefore needed to be removed, and an improvement in pain symptomatology was observed.

Likewise, Faldini et al.[16] also observed excellent results in the quality of life of patients who received subtalar arthroereisis with bioabsorbable implants at an average of four years follow-up. They had only four cases where the patient needed a second surgical procedure to remove the implant.

Giannini et al.[11], Zaret et al.[17], and Roth et al.[18] have demonstrated that the premature removal of the implant does not affect the foot position, which instead maintains a certain degree of correction and thereby allows good clinical results. This confirms the findings in our study, in which patients whose implants had loosened, even those in which the implant was removed, reported no

other postoperative changes or complications such as pain or difficulty walking.

The literature contains numerous studies, such as Giannini et al.[11], Jay et al.[13], Faldini et al.[19], and Ruozi et al.[20], that reported satisfactory clinical results for arthroereisis in pediatric patients. These results are related to the choice of surgical procedure. Arthroereisis has been proven to be a good alternative to osteotomy and arthrodesis in the treatment of these patients. It is a minimally invasive procedure that reduces joint movement without totally eliminating it. It promotes the neutralization of abnormal foot pronation, corrects calcaneal valgus, and increases the medial longitudinal arch in the growing child, where the placement of the implant into the sinus tarsi limits anterior and medial talar displacement[21,22].

The following are benefits of this technique: it is easy to execute, there is little or no interference with osteoarticular tissue of the sinus tarsi, it does not prejudice other surgical options in the future, and it lowers surgical morbidity and promotes subtalar joint stabilization (given the principle of correction of the initial deformity in planovalgus). As in this study, Faldini et al.[5] and Craveiro et al.[23] observed positive results in at least 85% of patients in terms of rapid recovery, little postoperative immobilization, and preservation of the joint's functional movement.

CONCLUSION

Arthroereisis with the interposition of synthetic polyethylene material in the sinus tarsi demonstrated significant results in pediatric patients with symptomatic FF, with significant clinical improvement and a high degree of satisfaction.

Authors' contributions: Each author contributed individually and significantly to the development of this article: LPB *(https://orcid.org/0000-0002-3423-2470) interpreted the results of the study, participated in the review process, approved the final version; CKB *(https://orcid.org/0000-0002-1997-5372) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; MSPC *(https://orcid.org/0000-0002-0758-2547) conceived and planned the activities that led to the study, participated in the review process, approved the final version; CDCCF *(https://orcid.org/0000-0003-3522-1076) conceived and planned the activities that led to the study, participated in the review process, approved the final version; RAEC *(https://orcid.org/0000-0001-5268-8677) participated in the review process, approved the final version; MABN*(https://orcid.org/0000-0003-010112-8295) participated in the review process, approved the final version. *ORCID (Open Researcher and Contributor ID).

REFERENCES

1. Giannini BS, Ceccarelli F, Benedetti MG, Catani F, Faldini C. Surgical treatment of flexible flatfoot in children - a four-year follow-up study. J Bone Joint Surg Am. 2001;83(Suppl 2 Pt 2):73-9.
2. Corte-Real N. Felicíssimo P. Pé plano infantil. Acta Ped Port. 1995; 26(4):191-6.
3. Scher DM, Bansal M, Handler-Matasar S, Bohne WH, Green DW. Extensive implant reaction in failed subtalar joint arthroereisis: report of two cases. HSS J. 2007;3(2):177-81.
4. Smith SD, Millar EA. Arthrorisis by means of a subtalar polyethylene peg implant for correction of hindfoot pronation in children. Clin Orthop Relat Res. 1983;(181):15-23.
5. Faldini, C, Mazzotti, A, Panciera, A, Perna, F, Stefanini, N, Giannini, S. Bioabsorbable implants for subtalar arthroereisis in pediatric flatfoot. Musculoskelet Surg. 2018;102(1):11-9.
6. Jerosch J, Schunck J, Abdel-Aziz H. The stop screw technique-a simple and reliable method in treating flexible flatfoot in children. Foot Ankle Surg. 2009;15(4):174-8.
7. 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.
8. Roth S, Roth A, Jotanovic Z, Madarevic T. Navicular index for differentiation of flatfoot from normal foot. Int Orthop. 2013;37(6): 1107-12.
9. Pavone V, Costarella L, Testa G, Conte G, Riccioli M, Sessa G. Calcaneo-stop procedure in the treatment of the juvenile symptomatic flatfoot. J Foot Ankle Surg. 2013;52(4):444-7.
10. Kelikian A, Mosca V, Schoenhaus HD, Winson I, Weil L Jr. When to operate on pediatric flatfoot. Foot Ankle Spec. 2011;4(2):112-9.
11. Giannini S, Cadossi M, Mazzotti A, Persiani V, Tedesco G, Romagnoli M, Faldini C. 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.
12. Dana C, Péjin Z, Cadilhac C, Wicart P, Glorion C, Aurégan JC. Long-term results of the "horseman" procedure for severe idiopathic flatfoot in children: a retrospective analysis of 41 consecutive cases with mean 8.9 year duration of follow-up. J Foot Ankle Surg. 2019;58(1):10-16.
13. Jay RM, Din N. Correcting pediatric flatfoot with subtalar arthroereisis and gastrocnemius recession. Foot Ankle Spec. 2013;6(2):101-7.
14. Rodrigues, RC, Masiero, D, Mizusaki, JM, Imoto, AM, Peccin, MS, Cohen, M et al. Tradução, adaptação cultural e validação do American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale. Acta Ortop Bras. 2008;16(2):107-11.
15. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2017. Avaible at: URL https://www.R-project.org/.
16. Faldini C, Mazzotti A, Panciera A, Persiani V, Pardo F, Perna F, Giannini S. Patient-perceived outcomes after subtalar arthroereisis with bioabsorbable implants for flexible flatfoot in growing age: a 4-year follow-up study. Eur J Orthop Surg Traumatol. 2018;28(4):707-712.

17. Zaret DI, Myerson MS. Arthroerisis of the subtalar joint. Foot Ankle Clin. 2003;8(3):605-17.
18. 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.
19. Faldini C, Nanni M, Traina F, Fabbri D, Borghi R, Giannini S. Surgical treatment of hallux valgus associated with flexible flatfoot during growing age. Int Orthop. 2016;40(4):737-43.
20. Ruozi B, Belletti D, Manfredini G, Tonelli M, Sena P, Vandelli MA, Forni F, Tosi G. Biodegradable device applied in flatfoot surgery: comparative studies between clinical and technological aspects of removed screws. Mater Sci Eng C Mater Biol Appl. 2013;33(3):1773-82.
21. Koning PM, Heesterbeek PJ, de Visser E. Subtalar Arthroereisis for Pediatric Flexible Pes Planovalgus. J Am Podiatr Med Assoc. 2009; 99(5):447-53.
22. Rossi C, Jucá RLL, Stefanello TD. A incidência de pé cavo, plano e normal em indivíduos com classe I, II e III de Angle [monografia]. Cascavel: Faculdade Assis Gurgacz; 2016.
23. Craveiro WA, Jorge R. Perfil das superfícies plantares de atletas amadores de corrida de rua em Brasília [monografia]. Brasília: Universidade Paulista; 2009.