

ORIGINAL ARTICLE

Treatment of painful flexible flatfoot in children after failed conservative treatment using a minimally invasive surgery technique

✉ Bojan Bukva^{ID 1,2}, Marko Majstorović^{ID 1,2}, Siniša Dučić^{ID 1,2}, Branislav Krivokapić^{ID 1,3}, Vladimir Radlović^{ID 1,2}, Goran Đuričić^{ID 1,4}, Ninoslav Begović^{ID 1,5}, Jasna Stojković^{ID 1,6}, Tatjana Knežević^{ID 1,6}, Dejan Nikolić^{ID 1,6}

¹Faculty of Medicine, University of Belgrade, Serbia

²Department of Pediatric Surgery, University Children's Hospital, Belgrade, Serbia

³Institute for Orthopedic Surgery "Banjica", Belgrade, Serbia

⁴Department of Radiology, University Children's Hospital, Belgrade, Serbia

⁵Institute for Mother and Child "Dr Vukan Čupić", Belgrade, Serbia

⁶Department of Physical Medicine and Rehabilitation, University Children's Hospital, Belgrade, Serbia

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✉ Correspondence to:

Bojan Bukva

University Children's Hospital,

10 Tiršova Street, 11000 Belgrade, Serbia

Email: bojanbukva@yahoo.com

Summary

Introduction/Aim: Flexible flatfoot (FFF) is one of the most common skeletal deformities in the pediatric population, especially in preadolescence. This retrospective observational study evaluates results of a calcaneal subtalar extra-articular arthrodesis (subtalar arthroereisis) with one cannulated screw for the treatment of painful flexible flatfoot in children, after previously failed conservative treatment.

Material and Methods: Preadolescent and adolescent pediatric patients were observed at the Department of Pediatric Orthopedic Surgery. The study included 28 feet of 15 children (5 girls and 10 boys) during a 6-year period, from 2016 to 2021 (average 36 months). The average age was 11.46 years (range 8-15 years). We performed the same operative technique under fluoroscopy for all patients. Radiographic parameters were taken before, after operative treatment, and after hardware removal. The following radiological parameters were measured: talo-calcaneal (TC), talo-navicular (TN), talo-first metatarsal bone (T1MT) and calcaneal pitch (CP) angles, in the anteroposterior and/or lateral views. Functional outcomes (extension and eversion of the foot) before surgery and after hardware removal were compared.

Results: After operative treatment, the midfoot radiographic parameters were not statistically significantly altered; however, the subtalar joint and forefoot were statistically significantly improved: both radiologically and clinically. The range of extension and eversion of the foot were remarkably reduced without disturbing the morphological and functional aspects of the talocrural and subtalar joints.

Conclusion: Extra-articular arthrodesis, using a cannulated screw is a minimally invasive technique, represents an optimal method for the operative treatment of symptomatic flexible flatfoot in children. This technique is simple, efficient and does not disrupt the anatomy of the foot.

Keywords: flexible flatfoot, extra-articular arthrodesis, minimally invasive surgery, children



INTRODUCTION

Flexible flatfoot (FFF) is the most common skeletal deformity in the pediatric population (1). It is represented as abnormally low, or absent, medial arch of the foot, in association with excessive eversion of the heel during weight-bearing and an abducted forefoot, producing a midfoot sag. During standing position on the toe tips, the longitudinal arch of the foot will reform because of the windlass mechanism of the plantar fascia.

Usually, FFF does not cause any symptoms. Rarely, FFF can cause calf or foot pain, gait disturbances or disability, at which point it becomes alarming (2). Factors that need to be taken into account in the treatment of FFF are: age, joint hypermobility, general hyperlaxity, degree of deformity and patient concerns (3,4). Initial treatment of FFF is physiotherapy and orthotics, but if those conservative methods fail, operative treatments should be considered (5). The goals of an operative treatment are: pain relief, foot alignment, stability of the foot during stance, and correction of an abnormal gait (5).

Extra-articular arthrodesis using a cannulated screw (subtalar arthroereisis) represents a minimal invasive surgical method of treatment. It involves the placement of an implant, or bone graft, within the sinus tarsi to restrict excessive motion at the subtalar joint. Subtalar arthroereisis corrects the hindfoot valgus deformity and restores plantar-flexion without overly disrupting the anatomy of the foot (2,6).

The aim of this study was to evaluate radiological and clinical parameters of a minimal invasive surgical technique for the treatment of flexible flatfoot in children, using an extra-articular arthrodesis with a cannulated screw, after failed conservative treatment.

MATERIAL AND METHODS

Study sample

We retrospectively analyzed the results of 28 feet (15 patients), aged from 8 to 15 years (average 11.46 ± 3.33 years), during a six-year period (from January 2016 to December 2021). This included 5 girls and 10 boys with lower leg or foot symptoms (pain and discomfort) after failed physiotherapy. The average follow-up was 26 months (range 18-78 months).

Inclusion criteria for this study was flexible flatfoot with pain or discomfort in the lower leg, calf or foot, in pediatric patients with open growth plates, with no previous surgeries of the foot, ankle or lower leg. According to Johnson and Strom classification system, all our patients were stage II, which include moderate swelling and tenderness along posterior tibial tendon, marked weakness in "heel-rise test", flexible positive deformity in talonavicular joint and positive "too many toes sign" (7).

Patients with systemic disease, neurological disorders and patients with chronic diseases or bone dysplasia were excluded. Patients on chemo- or radiotherapy and patients on corticosteroids were also excluded.

Ethical approval was obtained from the Human Ethics Research Committee.

Surgical procedure

An oblique dorso-lateral 2-cm incision was made over the sinus tarsi of the foot, following the natural skin lines. The underlying extensor brevis muscle was dissected from its surrounding tissues and retracted distally. The sinus tarsi was cleaned of all fat and soft tissue. The varus-valgus position of the heel was assessed on clinical examination intraoperatively. The calcaneus was rotated under the talus and the foot was held with the ankle in equinus and in inversion. Under fluoroscopic guidance, the threaded guidewire was driven from the talar neck projection line into the calcaneus (in the antero-posterior [AP] and lateral view). A short tunnel was drilled over the guidewire, followed by insertion of an AO (Arbeitsgemeinschaft für Osteosynthesefragen) cannulated screw (3.5-4.5mm diameter and 30-35 mm in length, depending on the size of the bone). During surgery, it is important that the screw does not enter the plantar cortex of the calcaneus. Postoperatively, a cast was not applied, with weight bearing occurring two days after surgery. The X-rays in the standing position (in AP and lateral view) were done during the first postoperative week. None of our patients had a triceps surae contracture, so elongation of the Achilles tendon was not performed.

Patients were evaluated according to the clinical and radiological findings. Following parameters were observed: demographic data (age, gender, side of surgery), clinical data (passive dorsiflexion and passive eversion of the foot), and radiological data [talo-calcaneal (TC), talo-navicular (TN), talo-first metatarsal bone (T1MT) and calcaneal pitch (CP)] in the antero-posterior (AP) and lateral (PRO) views]. Clinical and radiological data were correlated before surgery and after hardware removal (18-36 months after the surgery). Goniometer was used to measure clinical data and values were expressed in angle degrees.

Statistical analysis

Data was analyzed using the Kolmogorov Smirnov test (for examination of a variable's deviation from the normal distribution) and one-way repeated measures using ANOVA. Data was presented as mean and standard deviation. When required, the Bonferroni correction was used to assess particular significant differences. Partial eta squared (partial η^2) was used for effect size assessment. Type one error was set at $\alpha=5\%$. Statistical significance was set at a p-level of $p<0.05$. For statistical analysis of the data we used the data analysis software system Statistica for Windows (version 13.0., Dell Inc., Tulsa, OK, USA).

Table 1. Analysis of radiological parameters in the treatment of flexible flatfoot

Parameter	Before surgery*	After surgery*	F-value**	p-value**	η^2 value***
TC (AP)	28.11±8.11	21.14±7.26	93.309	p<0.001	0.776
TC (Lat)	29.64±8.61	23.64±7.44	26.321	p<0.001	0.494
T1MT (AP)	19.79±5.79	13.11±5.10	69.943	p<0.001	0.721
T1MT (Lat)	16.75±7.76	12.46±6.05	12.099	p=0.001	0.309
TN (AP)	16.36±5.79	15.07±6.35	2.178	p=0.152	0.075
TN (Lat)	11.25±4.93	11.43±6.40	0.012	p=0.914	0.000
CP	12.00±3.97	16.46±2.95	37.956	p<0.001	0.584

* Expressed in angle degrees (mean values±SD); ** One-way repeated measures ANOVA; *** Partial eta squared (partial η^2) for effect size assessment; TC (AP): talo-calcaneal angle in antero-posterior view; TC(Lat): talo-calcaneal angle in lateral view; T1MT (AP): talo-first metatarsal angle in antero-posterior view; T1MT (Lat): talo-first metatarsal angle in lateral view; TN (AP): talo-navicular angle in antero-posterior view; TN (Lat): talo-navicular angle in lateral view; CP: "calcaneal pitch" angle

RESULTS

We studied 28 feet (in 15 patients) with an average follow-up of 26 months (range 18-78 months). From all participants 13 out of the 15 patients had surgery on both feet. Using the Kolmogorov-Smirnov test, it was calculated that all observed variables consistently had a normal distribution. The data set had no significant outliers. We found no statistical significance in either radiological or clinical parameters between both left and right feet.

In analysis of radiological parameters, after the surgery there were statistically significant differences in the talo-calcaneal (TC), talo-firstmetatarsal (T1MT) and calcaneal pitch (CP) angles, while there was no statistical significance with respect to the talo-navicular (TN) angle (**Table 1**).

The values of radiological parameters related to hind-foot; the subtalar (talocalcaneal) joint (TC) and "calcaneal pitch" (CP), and to forefoot (T1MT) were significantly improved after the surgery, whereas there was mild improvement in midfoot values, expressed in talo-navicular (TN) angle values.

When comparing pre- and post-surgery assessment, most improvement was seen in the clinical parameters (range of extension and eversion) (**Table 2**). Passive extension and eversion of the foot were statistically improved before and after the surgery (**Table 2**).

DISCUSSION

Many surgical procedures for the correction of symptomatic flexible flat feet (FFF) have been proposed. The ideal operative procedure should result in a painless foot

and lower leg, with a physiological longitudinal arch, full range of motion and function of the talocrural and subtalar joints (2). Operative treatment of FFF is rarely indicated and should not be performed under the age of eight years (2). In all cases, contracture of the triceps surae muscles should be corrected.

Operative procedures can be classified as:

- soft tissue procedures (plications, tendon transfers, tendon lengthening)
- bone and joint procedures (osteotomies, bone excisions, arthrodesis)
- use of implants (bone or synthetic) into the calcaneus into the sinus tarsi (8-14)

Chronic pain and gait disturbances are possible and rare complications of subtalar arthrodesis (15). In 1972, Recardo Alvarez published the original technique for subtalar extra-articular arthrodesis (subtalar arthroereisis) – since then, many variant techniques have been reported (16). Subtalar arthroereisis has an immediate mechanical effect, in elevation of the talus in sinus tarsi, without any disruption of foot anatomy. It also has a proprioceptive effect, controlling the compressive and directional muscular forces (17). The subtalar joint has a critical role in proprioception of the foot in contact with the ground (17). Some authors propose that sinus tarsi pain originates mostly from mechanoreceptors and nociceptors (17,18). However, some publications showed that patients with sinus tarsi pain and instability in the subtalar joint have a prolonged peroneal reaction time (PRT), causing irregular peroneal muscle activity, ultimately leading to pain and instability in the sinus tarsi (19-21). In this retrospective study with cannulated screw insertion into sinus tarsi in patients with painful flatfeet, the radiological

Table 2. Analysis of clinical parameters in the treatment of flexible flatfoot.

Parameter	Before surgery*	After surgery*	F-value**	p value**	η^2 value***
Extension	24.75±7.25	11.68±7.76	293.668	p<0.001	0.916
Eversion	18.93±5.33	6.18±5.08	303.263	p<0.001	0.918

* Expressed in angle degrees (mean values±SD); ** One-way repeated measures ANOVA; *** Partial eta squared (partial η^2) for effect size assessment

and clinical improvement was obtained, particularly in the forefoot and hindfoot. And the most important, all participants were painless after the surgery.

In this study, the major complaint for all participants was forefoot supination and intoeing gait after surgery, which we did not consider as complication. Also, we did not consider the effusion in the subtalar joint and in the sinus tarsi as the complication. All of those signs were temporary, and resolved 3 months post-surgery. The major complication in this study (occurring in one participant) was the perforation of the distal part of the calcaneus by the cannulated screw, requiring subsequent screw removal.

Some authors report that fracture of the fourth metatarsal bone can occur in corrective surgical techniques, since the fifth ray of the foot is more mobile and contraction of the peroneal muscles due to the antalgic position of the foot occurs (16). There were no such complications in patients in this study.

There are limitations to this study: a small number of patients, retrospective, no qualitative patient satisfaction survey and there was no control group of children with symptomatic FFF treated using a different surgical technique for comparison.

CONCLUSION

Most children with flexible flatfeet are asymptomatic and do not require treatment. Symptomatic children, however, may benefit from conservative (non-operative) treatment. Non-operative treatment (physical therapy, shoe insoles and orthotics) is usually successful. If this fails, operative treatment is an option. Extra-articular arthrodesis, using a cannulated screw (subtalar arthroereisis), remains an excellent method for surgical flexible flatfeet correction. It does not disrupt the physiological function, or the anatomy of the foot, and has immediate beneficial post-surgery effects. The technique is simple, easily and quickly performed with the screw providing mechanical support and a beneficial proprioceptive effect in the sinus tarsi. The mechanical load over the medial side of the foot (talo-naviculo-cuneiform joint, plantar aponeurosis and medial ligaments) is minimized and an ideal physiological load balance of the foot can be achieved. Indications for surgery must be precise to avoid any possibility of overtreatment.

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LEČENJE BOLNOG RAVNOG STOPALA KOD DECE KORIŠĆENJEM MINIMALNO INVAZIVNE HIRURŠKE PROCEDURE NAKON NEUSPELOG KONZERVATIVNOG LEČENJA

Bojan Bukva, Marko Majstorović, Siniša Dučić, Branislav Krivokapić, Vladimir Radlović, Goran Đuričić, Ninoslav Begović, Jasna Stojković, Tatjana Knežević, Dejan Nikolić

Sažetak

Uvod: Fleksibilno ravno stopalo je jedan od najčešćih deformiteta u pedijatrijskoj populaciji, naročito u periodu preadolescencije. Ova retrospektivna opservaciona studija se odnosi na evaluaciju rezultata lečenja ekstra-artikularnom subtalarnom artrodezom pomoću jednog kanuliranog zavrtnja (subtalarna artroereiza), u lečenju bolnih ravnih stopala, a nakon neuspelog konzervativnog lečenja,

Materijal i metode: Ispitanici su bili preadolescenti i adolescent lečeni na Odeljenju dečje ortopedije i traumatologije Univerzitetske dečje klinike u Beogradu. Studija je obuhvatala ukupno 28 stopala, odnosno 15 dece (5 devojčica i 10 dečaka), tokom perioda od 6 godina (prosečno 36 meseci). Prosečni uzrast pacijenata je bio 11.46 godina (opseg 8-15 godina). Svi pacijenti su lečeni istom hirurškom procedurom pod kontrolom RTG pojačivača slike. Radiografski parametri su mereni pre i posle hirurške intervencije, kao i posle vađenja osteosintetskog materijala. Posmatrali smo sledeće radiografske parametre: talo-kalkanearni (TC), talo-navikularni (TN), talo-prvi metatarzalni ugao (T1MT) i uzdignutost petne kosti ("calcaneal pitch" -CP) u antero-posteriornoj i profilnoj

projekciji. Takođe, poredili smo funkcionalne (kliničke) rezultate, u vidu stepena opružanja (ekstenzije) i izvrtnja (everzije) stopala pre hirurške intervencije, posle intervencije i nakon vađenja osteosintetskog materijala.

Rezultati: Nakon hirurškog lečenja navedeni radiografski parametri u nivou srednjeg dela stopala nisu statistički značajnije promenjeni u odnosu na preoperativne, ali u nivou prednjeg segmenta stopala i subtalarnog zgloba navedeni klinički i radiografski parametri su značajno poboljšani. Obim pokreta opružanja (ekstenzije) i izvrtnja (everzije) su statistički značajno redukovani, bez morfoloških i funkcionalnih poremećaja talokruralnog i subtalarnog zgloba.

Zaključak: Ekstra-artikularna subtalarna artrodeza pomoću jednog kanuliranog zavrtnja, kao metoda minimalno invazivne hirurške procedure, predstavlja optimalni metod hirurškog lečenja simptomatskih fleksibilnih ravnih stopala kod dece. Ova tehnika je jednostavna za izvođenje, efikasna i ne remeti fiziološku anatomiju stopala.

Vrsta studije: retrospektivna studija, nivo dokaza IV

Ključne reči: fleksibilno ravno stopalo, subtalarna artroereiza; minimalno invazivna hirurgije, deca, pedijatrija

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