

## Calcaneo-stop procedure for paediatric flexible flatfoot

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### Abstract

**Background** Flexible flatfoot is a frequent deformity found in children. The aim of this study is to evaluate the pedographic outcome of the percutaneous arthroereisis with the use of a screw through the sinus tarsi into the talus.

**Materials and methods** 43 calcaneo-stop procedures of 25 patients (18 bilateral, seven unilateral) were evaluated. Mean age at surgery was 10 years (7–14, SD 2.2) (SD: standard deviation), mean follow-up time was 9.7 months (3–19, SD 5.5). Patient satisfaction rate was recorded, the Meary's talus-first metatarsal angle was measured with lateral radiograms, and a dynamic pedographic assessment was also performed.

**Results** Patient satisfaction rate was excellent for 33 feet of 19 children, good for eight feet of five children, and poor for either feet of one child. We did not observe any complications during or following the surgery. The mean rest heel valgus decreased from 13.4° (10°–17°, SD 1.5) to 2.8° (0°–6°, SD 1.7) post op. The Meary's angle improved from

160.2° (148°–177°, SD 6.8) to 175.9° (167°–179°, SD 3.5). By pedographic analysis, the area and the pressure–time integral (load amount, PTI) values increased on the lateral regions of the sole (except for the lesser toes) and decreased on the medial areas (except for the hallux). The relative contact time in the lateral midfoot increased from 63.8% (39.6–78.4%, SD 10.6) to 75.1% (50–86.1%, SD 9.4), and that in the lateral forefoot region from 81.2% (60.4–89.2%, SD 6.6) to 86.8% (78.1–97.1%, SD 4.8).

**Conclusion** The calcaneo-stop procedure is a simple and reliable method for the correction of severe flexible paediatric flatfoot. Our prospective, short-term results following the anterograde screw implantation into the talus correlate well with the results of similar or different arthroereisis methods. Further investigations are required to evaluate the long-term outcome of the screw calcaneo-stop method, including the conditions following implant removal.

**Keywords** Pes planovalgus · Flatfoot · Arthroereisis · Calcaneo-stop

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### Introduction

Flatfoot is a progressive acquired or developmental deformity that represents flattening of the medial arch, plantar and medial rotation of the talus and the forefoot abduction [1]. Flexible flatfoot is characterized by a normal medial arch during non-weight bearing and an absence of the medial arch accompanied by a medial protrusion of the head of the talus and a valgus position of the calcaneus under weight bearing. Flexible flatfoot is so frequent deformity in the childhood, that some authors rank it as an anatomical variant caused by loose ligaments rather than a sickness, requiring no treatment at most of the cases [2–4], however,

they advise periodical follow-ups during the growing-up age, recording any signs of progression. Others claim that paediatric flatfoot may be a basis for numerous painful deformities in the adulthood, the authors recommend early treatment [5, 6].

Majority of the flexible flatfeet show an advance following foot exercises, or usage of medial arch supporting the insoles or the orthopaedic shoes. However, approximately in 5% of the cases, where valgus deformity of the heel is severe, conservative therapy often fails [7].

The operative treatment of the flexible calcaneovalgus can be divided into three main groups: reconstruction, arthrodesis and arthroereisis. Soft tissue reconstruction is rarely used as a separate procedure. Bony reconstruction of the forefoot, the midfoot and the hindfoot may give excellent results, however, the long-term results are still questioned [8]. Triple arthrodesis remains the salvage method for failed primary procedures.

The arthroereisis of the subtalar joint, which involves the limitation of the pronation in the talocalcaneal joint, is widely used; numerous methods are published [6, 9–15].

In the past decade, the calcaneo-stop procedure gained more interest. This method achieves limitation of the subtalar joint pronation through proprioceptive foot receptors rather than a mechanical barrier [5, 16, 17]. Numerous publications evaluate clinical results of this procedure [16, 18, 19]; however, we found only one publication on combined radiological and pedographic assessment of the calcaneo-stop method [19].

The purpose of this prospective study was to evaluate the pedographic outcome of our consecutive planovalgus cases treated by percutaneous arthroereisis with the use of a screw through the sinus tarsi into the talus.

## Materials and methods

### Patients

From August 2008 to January 2010, we performed 44 calcaneo-stop procedures on 26 children. Of these, 43 feet (19 right, 24 left) of 25 patients (18 males, 7 females) were available for evaluation. 18 patients underwent bilateral surgery; of these, three were one-stage procedures. Seven patients had unilateral intervention. Mean age of the 43 cases at surgery was 10 years (7–14, SD 2.2) (SD: standard deviation); mean follow-up time was 9.7 months (3–19, SD 5.5).

### Indication for surgery

A calcaneo-stop procedure for the correction of an idiopathic flexible flatfoot was indicated when all means of

conservative treatments were ineffective for the reduction of planovalgus, a Meary's talus-first metatarsal (TFM) angle less than 170° on lateral radiogram was recorded, and the deformity induced pain or fatigue. Age limit was 7–14 years.

Contraindications were children outside the age limits, neurological or neuromuscular disorders, congenital or post-traumatic flatfoot.

### Operative technique

General anaesthesia was used, without tourniquet. The patient was placed supine, with the operated extremity rotated slightly inwards. The foot was hanging free at the end of the operating table to allow clear fluoroscopic control. The sinus tarsi was palpated and a K-wire was driven percutaneously into the body of the talus under fluoroscopic check. The position of the K-wire was determined as 6–7 mm medially from the lateral cortical of the talus on antero-posterior view, and pointing to the apex of the talus dome on lateral view. An incision of 1 cm was applied around the K-wire. The soft tissues were dissected bluntly. Then a cannulated self-drilling self-tapping screw (BoneStar®, Instrumentaria PLC, Sesvete, Croatia) of desired length (30, 35 or 40 mm) was driven into the talus (Fig. 1). After removal of the K-wire, the dorsiflexion of the foot was checked with the knee in extended position; none of the cases needed an Achilles tendon lengthening, as all of them could provide at least 5° of foot dorsiflexion after the insertion of implant. For wound closure, a single skin stitch was used. The proper description of the procedure with the use of the BoneStar® implant was first published by Roth [20].

No external fixation was used. Patients were allowed for full weight bearing as soon as possible. Foot exercises were recommended post-operatively.

The screws are scheduled for removal using the formula: (child's age in years) × 2 + 6 months following the operation [5].

### Methods of evaluation

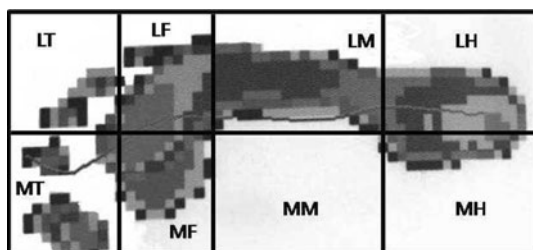
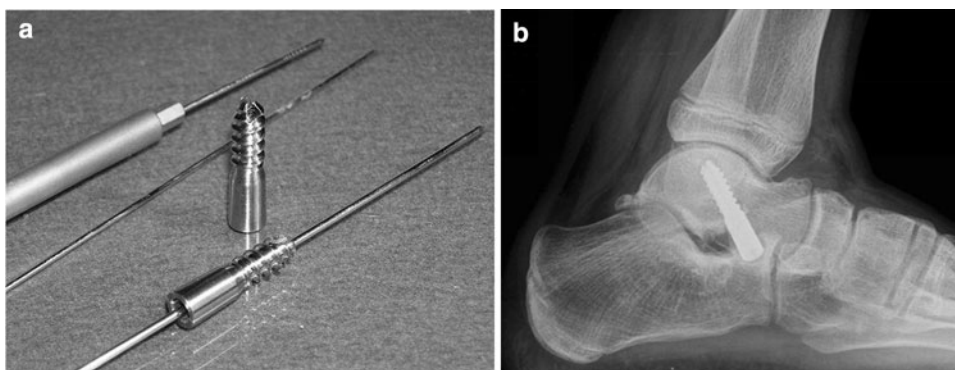
A standard visual analogue scale was used for rating the patient satisfaction. 0–5 points were graded as poor, 6–8 points were considered as good and 9–10 points as excellent outcome from patient's point of view.

Radiological assessment was performed on loaded lateral radiograms pre-operatively and 3–5 months post-operatively. The TFM angle was measured as described by Pehlivan et al. [21].

A dynamic pedographic record was obtained for all participant cases pre-operatively and 3–5 months post-operatively. For the data recording, the EMED SF 101B pedography analyser with a 102H platform (Novel

**Fig. 1** The BoneStar® screw and its insertion into the talus.

**a.** The BoneStar® cannulated screw and its screw driver,  
**b.** positioning of the self-tapping screw into the talus



**Fig. 2** The division of the footprint into sections. *LT* lateral toes, *MT* medial toes, *LF* lateral forefoot (metatarsal heads), *MF* medial forefoot (metatarsal heads), *LM* lateral midfoot, *MM* medial midfoot, *LH* lateral heel, *MH* medial heel

GmbH, Munich, Germany) was used. The resolution of the platform is 4 sensors/cm<sup>2</sup>, the data gathering frequency is 50 s<sup>-1</sup>. A multi-step method was applied, when the patient is able to gain his/her normal walking velocity before taking a step onto the pressure sensitive platform and walking through it continuously. Contact area, contact time and pressure–time integral values were evaluated according to the total foot and the separate smaller sections of the footprint as well. The division of the foot into areas can be seen in Fig. 2.

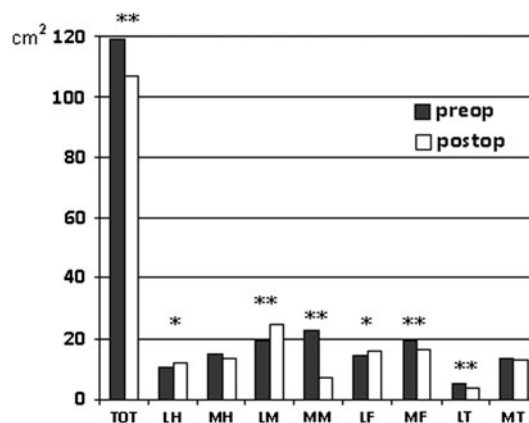
For statistical analysis, the Student *t* test was used (level of significance: \**p* < 0.05, \*\**p* < 0.001).

## Results

### Patient satisfaction rate

Of the 43 operated feet of 25 children, 33 feet (77%) of 19 children had excellent, 8 feet (19%) of 5 children had good, and 1 child's 2 feet (4%) gained poor outcome, however, the poor case had the highest body mass index (29.9) of all the cases.

Five children experienced an ease of their previously existing lower back pain following the surgery.



**Fig. 3** Changes in the area values of the foot and its sections following the surgery. *TOT* total foot, for abbreviations of the sections, see Fig. 2

### Complications

We did not observe any complication among the 43 procedures in the 25 patients.

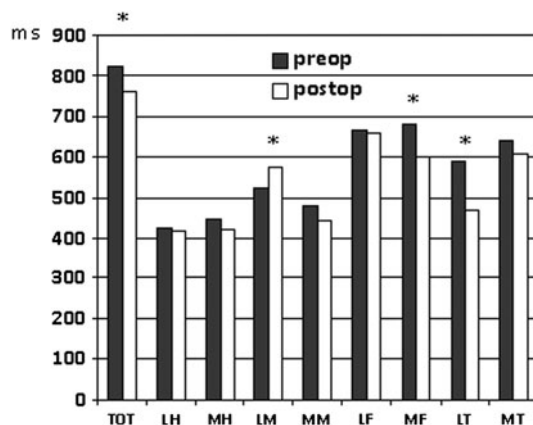
### Heel alignment

The mean rest heel valgus decreased from the pre-operative 13.4° (10–17, SD 1.5) to 2.8° (0–6, SD 1.7) post-operatively (*p* < 0.05).

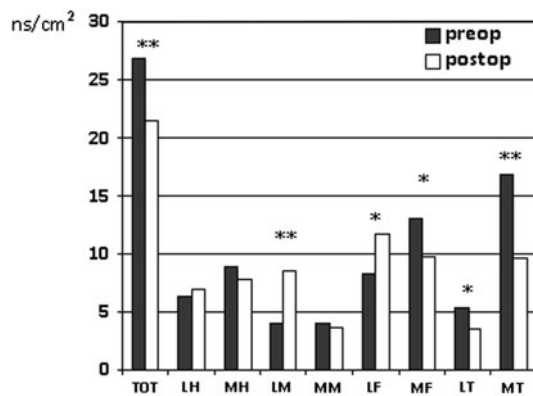
On the lateral radiograms, the mean TFM angle improved from the pre-operative 160.2° (148–177, SD 6.8) to 175.9° (167–179, SD 3.5) post-operatively (*p* < 0.001).

### Pedographic analysis

The area values of the foot and its sections can be seen in Fig. 3. The total foot contact area decreased from 118.9 cm<sup>2</sup> (82–176 cm<sup>2</sup>, SD 27.2) to 106.6 cm<sup>2</sup> (73–149 cm<sup>2</sup>, SD 20.9) (*p* < 0.001). A decrease in the area of the medial sections and an increase in the lateral parts was found.



**Fig. 4** Changes in the contact time values of the foot and its sections following the surgery. *TOT* total foot, for abbreviations of the sections, see Fig. 2



**Fig. 5** Changes in the pressure–time integral values of the foot and its sections following the surgery. *TOT* total foot, for abbreviations of the sections, see Fig. 2

The contact time values of the foot and its regions are shown in Fig. 4.

The relative contact time (the actual contact time of the region divided by the contact time of the total foot in percent) increased in the lateral midfoot (LM) region from the pre-operative 63.8% (39.6–78.4%, SD 10.6) to a post-operative 75.1% (50–86.1%, SD 9.4) ( $p < 0.001$ ) and that in the lateral forefoot (LF) region raised from 81.2% (60.4–89.2%, SD 6.6) to 86.8% (78.1–97.1%, SD 4.8) ( $p < 0.001$ ). At the remaining sections, with the numbers available, no significant difference could be detected in the relative contact time data.

The pressure–time integral values of the foot and the sections are summarized in Fig. 5.

## Discussion

Flexible flatfoot is a frequent condition in the childhood. If the deformity is accompanied by the difficulties with high

physical activity or pain in the foot or the ankle region, treatment of the flatfoot is necessary. When conservative therapy fails, a surgical correction may be considered. Of the available surgical procedures, the arthroereisis of the talo-calcaneal joint with either an endo-orthotic implant or a screw is widely used method. A huge variety of implants for the correction of flexible flatfoot have been published. LeLivre [10] in 1970 filled the tarsal sinus with structural bone graft. Smith [13] used polyethylene peg with a 96% success rate. In 1997, Verheyden [14] first reported the use of a spacer into the sinus tarsi. Viladot [15] applied a silicone implant, with an excellent outcome in 99%. Giannini [9] in 1998 published good results following implantation of bioabsorbable expanding material at 20 cases, with a 94% success rate.

In 1970, R. Alvarez described the technique of subtalar screw arthroereisis; however, this method became widely known and was used in the early 1980s [22, 23]. Placement of the screw maintains correction of heel valgus by stimulating the proprioceptive receptors around the sinus tarsi and forces the hindfoot into a reduced position. Numerous authors emphasized the importance of this proprioceptive mechanism in maintaining the calcaneus in neutral position [5, 16, 17].

The screw can be allocated into the processus lateralis tali [5, 19, 24], or into the calcaneus [16, 18]; the two alternatives seem to have no significant difference according to the surgical complexity, post-operative care and outcome. However, implant design may improve the success of the procedure by reducing implant fracture and malposition. Our surgical technique for the calcaneo-stop procedure was the insertion of a cancellous cannulated screw into the talus as described by Castaman [24]. The implant (BoneStar® screw, see Fig. 1.) was developed by Roth for the specific use of anterograde talus implantation technique. Its cannulated body and wider core diameter (compared with the standard AO cancellous screw) is responsible for the avoidance of malposition and implant fracture. Excellent results with the BoneStar® implant were published by Roth [20], while he described an incorrect screw position rate of 7.45%, and a fracture rate of 9.57% with the use of 6.5 mm AO screws [5]. In our study, no malposition was observed, due to the cannulation technique and the intra-operative fluoroscopic control; neither had we found any fracture of the implanted BoneStar® screws.

Jerosch published a significant decrease in the calcaneo-valgus (from 12.2° to 5.2°) and increase in the TFM angle (162°–174°) following the 21 calcaneo-stop procedures, using standard AO cancellous screws driven into the calcaneus [18]. The study contained a static postural footprint analysis with a five grade (0–4) seriousness scale as well [15]; pre-operatively, 11 cases were rated as grade 4 (worst podogram), 8 were grade 3 and 2 were grade 2, while post-operatively 17



cases were rated as normal, 2 cases were grade 1 and 2 were grade 2. 2 of the 21 patients experienced subjective limitations in their daily life following the operation. We experienced similar rate of poor outcome: 2 from 43 feet (one patient's bilateral feet) has residual complaints during walking.

Giannini published 4 year follow-up results with reabsorbable poly-L-lactic acid (PLLA) implant (21 patients, aged from eight to 15 years) [25], where the Meary's angle improved from 164° to 174°, while the rest heel valgus decreased from 11.4° to 5.8°. The rest footprint scale as described above was also used; the mean footprint grade decreased from 2.6 to 0.8. An impingement of the PLLA absorbable implant at two from 21 cases was observed, which resolved spontaneously with the complete resorption of the material.

In our study, the mean rest heel valgus decreased significantly from 13.4° to 2.8° following the calcaneo-stop procedure. The Meary's angle improved significantly from 160.2° to 175.9°. These results highly correlate with those observed by Terebessy [19], where an improvement of the Meary's angle from 157.5° to 171° at 28 cases following anterograde insertion of AO screw into the talus was measured. Terebessy also evaluated the dynamic pedographic conditions of their 28 cases, where a lateral shift of the load on the sole and the decreased function of the great toe was found following the calcaneo-stop procedure. Our pedographic data provided similar results, the area, relative contact time and pressure-time integral (load amount, PTI) values increased on the lateral sections of the sole (except for the lesser toes) and decreased on the medial areas (except for the hallux), in the midfoot and metatarsal region the changes are significant. The great toe seems to be aligned in a relatively lifted position, as shown by the significantly decreased post op PTI and contact time value of this region.

The calcaneo-stop procedure is a simple and reliable method for the correction of severe flexible paediatric flatfoot by aligning the talus and the calcaneus into normal position and maintaining the situation through proprioceptive stimuli arising from the sinus tarsi. Our prospective, short-term results following the anterograde screw implantation into the talus seem to correlate well with the results of similar or different arthroereisis methods. However, further investigations are required to evaluate the long-term outcome of the screw calcaneo-stop method, including the conditions following implant removal.

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