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Arthrorisis with calcaneostop screw in children corrects Talo-1st Metatarsal-Index (TMT-Index)

Martinus Richter MD, PhD[1,*], Stefan Zech MD

Department for Foot and Ankle Surgery Rummelsberg and Nuremberg, Germany

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ABSTRACT

Background: Arthrorisis (other terms: Arthrorhisis or Arthroreisis) with calcaneostop screw is one option for the treatment of flatfoot (Pes abductoplanovalgus) in children. The aim of the study was to analyze the amount of correction (for example Talo-1st Metatarsal-Index (TMT-Index)) and clinical outcome including pedographic assessment.

Methods: In a prospective consecutive non-controlled clinical follow-up study, all patients that were treated with arthrorisis with calcaneostop screw from September 1st 2006 to August 31st, 2009 were included. One foot was operated at a time, and the contralateral foot was operated 3 months later if indicated. Postoperatively, 15 kg partial weight-bearing was performed for 6 weeks. The screws were removed after 2-year-followup. Assessment was performed before surgery, at two-year-followup, and at 2.5-year-followup. The assessment staging of posterior tibialis insufficiency, radiographs with full weight bearing (TMT-Index), pedography, and Visual-Analogue-Scale Foot and Ankle (VAS FA).

Results: 18 patients/31 feet were included in the study (age, 10.6 [8–12], 45% male). No complications were observed. In comparison with the preoperative parameters, the parameters posterior tibialis insufficiency stage, percentage of increased pedographic midfoot contact area and force were decreased, and TMT dorsoplantar/lateral/Index and VAS FA scores were increased at both followups (each $p < .05$). The parameters did not differ between followups (each $p \geq .4$).

Conclusions: All relevant parameters (stage of posterior tibialis insufficiency, TMT dorsoplantar/lateral/Index, pedographic midfoot contact area and force, VAS FA) improved after arthrorisis with calcaneostop screw (before and after screw removal) in pes abductoplanovalgus in children. Since the complication rate is very low, this method allows safe and predictable correction.

1. Introduction

Arthrorisis with calcaneostop screw has been proven to be a safe and effective method for correction of pes abductoplanovalgus in children [1–5]. The aim of the study was to analyze the amount of correction (for example Talo-1st Metatarsal-Index (TMT-Index)) and clinical outcome including pedographic assessment.

2. Methods

2.1. Technique [2]

This treatment was indicated following our treatment algorithm (Table 1). A longitudinal incision of approximately 3 cm was performed at the anterior border of the posterior subtalar joint facet. The subtalar joint was opened and the anterior border identified. Drilling into the calcaneus with a 3.2 mm drill was performed with the subtalar joint in maximal possible supination directly anterior to the joint surface directed towards plantar, medial and distal. A 4.5 mm cancellous screw with short thread portion was inserted (length, 30 or 35 mm). The screw was inserted until the screw head was roughly positioned above the anterior part of the joint surface or the calcaneal posterior subtalar joint facet (Fig. 1a). The screw was then further inserted or backed off until the hindfoot was looked in neutral position being unable to move to valgus, and until the TMT-Index was approximately slightly (around 5°) positive assessed fluoroscopically under simulated weight bearing conditions (Fig. 1b). A gastrocnemius-slide was performed if ankle dorsiflexion with extended knee was less than 10° with positive Silverskiöld-test after insertion of the screw [6–8]. We would have indicated a percutaneous Achilles tendon lengthening if ankle dorsiflexion was not possible with negative Silverskiöld-test after insertion of the screw [6]. One foot was operated at a time, and the contralateral foot was operated 3 months later following the

* Corresponding author at: Department for Foot and Ankle Surgery Rummelsberg and Nuremberg, Location Hospital Rummelsberg, Rummelsberg 71, 90592 Schwarzenbruck, Germany. Tel.: +49 9128 50 43450; fax: +49 9128 50 43260.
E-mail addresses: martinus.richter@sana.de, info@martinusrichter.de, 3600-894@online.de (M. Richter).
[1] Home page: http://www.foot-surgery.eu.

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Table 1
Treatment algorithm for pes adductoplanovalgus in children.

TMT-Index	Age < 7	Age 8,9	Age 10–12	Age > 12
Grade 1 0 to −20	Wait, yearly control	Wait, yearly control, when post. tib. insuff.: PT + ISO	When post. tib. insuff.: Arthrorisis	Wait, yearly control, when post. tib. insuff.: PT + ISO
Grade 2 −21 to −40	Wait, yearly control	Wait, yearly control, when post. tib. insuff.: PT + ISO	Arthrorisis	Osteotomy + soft tissue correction
Grade 3 −41 to −60	Wait, yearly control, PT, ISO	Arthrorisis	Arthrorisis	Osteotomy + soft tissue correction
Grade 4 <−61	Yearly control, PT, ISO, optional Arthrorisis	Arthrorisis	Arthrorisis	Osteotomy + soft tissue correction optional Arthrodesis when arthrosis/coalition/not reducible

TMT-Index, Talo-1st Metatarsal-Index; post.tib. insuff., posterior tibials tendon insufficiency (stages described in Table 2); PT, physiotherapy; ISO, in-shoe-orthosis based on pedography.

same treatment algorithm. Postoperatively, 15 kg partial weight-bearing was performed in a standard shoe for 6 weeks. After 6 weeks, full weight-bearing without restrictions was allowed. The screws were removed after 2-year-followup (both sides at the same time).

2.2. Study design

In a prospective consecutive non-controlled clinical followup study, all patients that were treated with arthrorisis with calcaneostop screw based on the treatment algorithm (Table 1) from September 1st 2006 to August 31st, 2009 were included. No exclusion criteria were defined. The assessment before treatment and at followup included clinical examination (with staging of posterior tibialis insufficiency as defined in Table 2) radiographs with full weight bearing (TMT dorsoplantar, lateral, Index), pedography (midfoot contact area and force percentage in relation to available physiological pedographic data), and Visual-Analogue-Scale Foot and Ankle (VAS FA) [9,10]. The clinical assessment was performed by the two authors who were the Director and Assistant Director of the Department for Foot and Ankle Surgery. For detection of potential weakness after gastrocnemius-slide, a test with single leg heel-rise for ten times was performed at followup.

2.3. Radiographic assessment (Fig. 2)

Dorsoplantar and lateral digital radiographs in standing position with bipedal full weight bearing were obtained. The radiographs were measured digitally with a software (Medicad2, Hectec, Landshut, Germany). The Talo-1st Metatarsal (TMT) angle was defined as the angle created between the axis of the 1st metatarsal and the talus. These axes were defined as the straight line between the centres of two circles that were placed in congruence with the outlines of the bones, one distal and one proximal at each bone. The TMT angles were defined to be negative

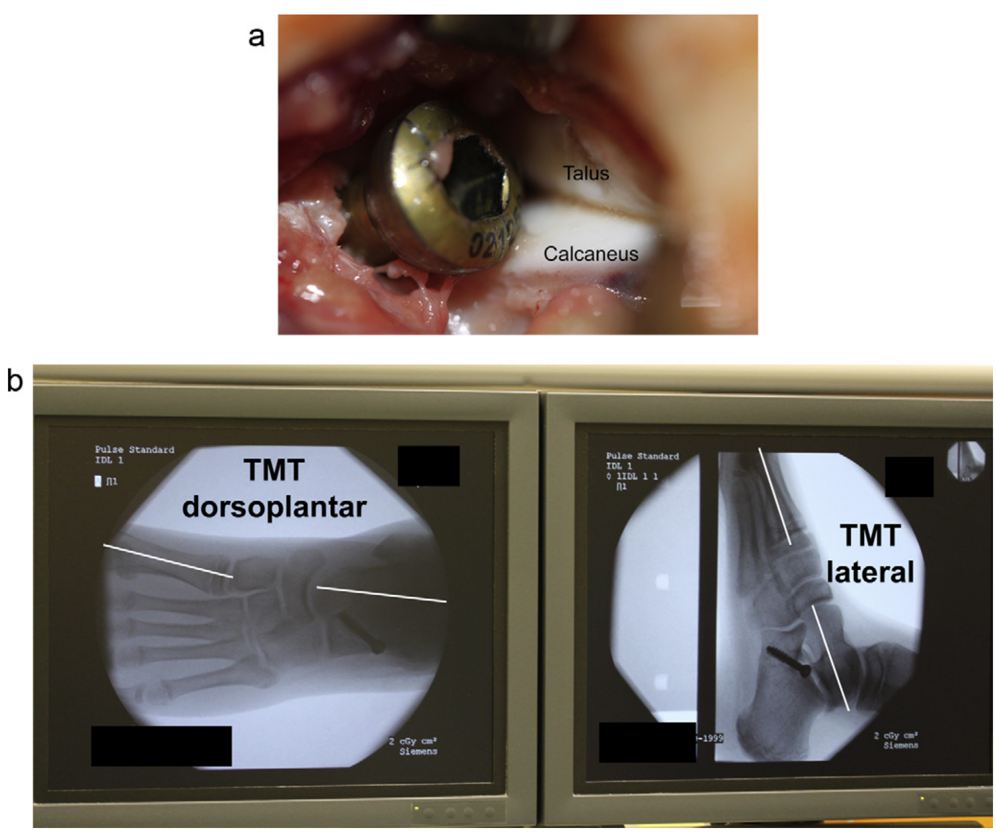

Fig. 1. (a and b) (a) shows the situs with the screw placed. (b) shows the intraoperative fluoroscopic assessment with TMT angles dorsoplantar and lateral during simulated weight-bearing.

Table 2
Posterior tendon insufficiency classification [18].

Stage 1	Single leg heel-rise possible, heel moves to varus during heel-rise
Stage 2	Single leg heel-rise possible, heel moves to neutral during heel-rise
Stage 3	Single leg heel-rise possible, heel stays in valgus during heel-rise
Stage 4	Single leg heel-rise not possible

for abduction in the dorsoplantar radiograph and for dorsiflexion in the lateral radiographs. The TMT-Index was defined as the sum of the dorsoplantar and lateral TMT angles [9].

2.4. Pedography

Standard dynamic pedography (three trials, walking, third step, mid stance force pattern) was performed as described before [11–13]. A standard platform (Emed AT®, Novel Inc., Munich, Germany & St. Paul, MN, USA) and software (Emed ST®, version 12.3.18, Novel Inc., Munich, Germany & St. Paul, MN, USA) was used. Both sides were measured. Computerized mapping to create a distribution into the following foot regions was performed with the standard software (Automask, version 12.3.18, Novel Inc., Munich, Germany & St. Paul, MN, USA): hindfoot, midfoot, 1st metatarsal head, 2nd metatarsal head, 3rd metatarsal head, 4th metatarsal head, 5th metatarsal head, 1st toe, 2nd toe, 3rd-5th toe. This mapping process does not include manual determination of landmarks [14]. The percentages of the midfoot contact area and force were compared with physiologic data [13].

2.5. Inter- and intraobserver repeatability

Bland and Altman plots and repeatability coefficients were used as measures of inter- and intraobserver repeatability for radiological measurements and assessment of posterior tibialis insufficiency stage [15]. The 95% limits of agreement represent a judgement of how well the measurements of the two reviewers (MR, SZ) agreed. By definition, the measurement error was smaller than the repeatability coefficient for 95% of the observations.

2.6. Statistics

An unpaired *t*-test was used for statistical comparison of VAS FA and TMT angles/Index before surgery and at followup, and a Chi^2-test for all other parameters.

3. Results

18 patients/31 feet were included in the study (age, 10.6 [8–12], 45% male). Gastrocnemius slide was performed in 25 (81%) cases and Achilles tendon lengthening was not performed. No complications were observed and all feet achieved full weight bearing during the 7th postoperative week. Table 3 shows the relevant parameters. In comparison with the preoperative parameters, the parameters posterior tibialis insufficiency stage, percentage of increased midfoot contact area and force were decreased, and TMT dorsoplantar/lateral/Index and VAS FA scores were increased at both followups (each $p < .05$). The parameters did not differ between followups (each $p \geq .4$). All subjects completed the test for detection of potential weakness after gastrocnemius-slide successfully for both legs.

The pre- and postoperative inter- and intraobserver repeatability coefficients for the measurement of the TMT angles and the posterior tibialis insufficiency stage were >0.75.

4. Discussion

Paediatric flexible flatfoot (pes abductoplanovalgus) is a common deformity for which a small, but significant number undergo corrective surgery [4]. Arthrorisis is a technique for treating flexible flatfoot by means of inserting a prosthesis into the sinus tarsi [4]. The use of the so-called calcaneostop screw is in possible option for arthrorisis, others are placement of the screw into the talus or implants that are inserted into the sinus tarsi [1–5]. Our results with the calcaneostop screw are comparable to different arthrorisis method reports regarding the clinical outcome [1–5]. The highest reported case number as such is 226 feet that has been published by the inventor of this technique [2]. This calls into question if our results are superimposed by the existing literature. However, we found no comparable data with followup after implant removal as presented in our study. Since, loss of correction after implant removal is a relevant concern, we feel that our data add something important to the literature [1–5]. Furthermore, our study is the first using a validated outcome score [16]. Based on our treatment algorithm, no patient would require surgery at followup. The complication rate was zero. The radiological parameters were significantly improved. There are some comparable measurements reported [1–5]. The best comparison is possible with the data reported by Hamel et al. [9]. However, we used a slight modification of determination of the

Table 3
Parameters before surgery, at 2-year-followup (with screws), and at 2.5-year followup (without screws).

Parameter/time of assessment	Before surgery	2-year-followup (with screws)	2.5-year followup (without screws)	Statistical analysis, test, p, 1st value, before versus 2-year-followup 2nd value, before surgery versus 2.5-year followup 3rd value, 2-year-followup versus 2.5-year followup
Posterior tibialis insufficiency stage (stages defined in Table 2)	None, $n = 0$ (0%) Stage 1, $n = 0$ (0%) Stage 2, $n = 19$ (61%) Stage 3, $n = 12$ (39%) Stage 4, $n = 0$ (0%)	None, $n = 16$ (52%) Stage 1, $n = 15$ (48%) Stage 2, $n = 15$ (0%) Stage 3, $n = 0$ (0%) Stage 4, $n = 0$ (0%)	None, $n = 15$ (48%) Stage 1, $n = 15$ (52%) Stage 2, $n = 0$ (0%) Stage 3, $n = 0$ (0%) Stage 4, $n = 0$ (0%)	Chi^2-test $p = .01/.02/.9$
TMT dorsoplantar	−15.1 (−24 to −6)	−1.7 (−8 to +4)	−2.3 (−9 to +2)	t-test, $p = .04/.05/.7$
TMT lateral	−20.5 (−36 to −5)	−1.1 (−8 to +4)	−2.4 (−8 to +2)	t-test, $p = .05/.05/.6$
TMT-Index	−35.7 (−52 to −11)	−2.8 (−12 to +5)	−3.4 (−12 to +3)	t-test, $p = .02/.03/.4$
Pedography, percentage increased midfoot contact area	$n = 26$ (84%)	$n = 4$ (13%)	$n = 5$ (16%)	Chi^2-test $p = .01/.01/.8$
Pedography, percentage increased midfoot force	$n = 28$ (90%)	$n = 5$ (16%)	$n = 5$ (16%)	Chi^2-test $p = .01/.01/.8$
VAS FA	82 (61–98)	95 (83–100)	94 (85–100)	t-test, $p = .05/.5/.8$

TMT-Index, Talo-1st Metatarsal-Index; VAS FA, Visual Analogue Scale Foot and Ankle.

1st metatarsal axis. Hamel proposed to use the perpendicular line through the basis of the 1st metatarsal, and we used the connection of the proximal and distal bone centre [9]. This modification was done to increase the accuracy and repeatability of defining this bone axis. We could justify this methodological modification with sufficient repeatability coefficients which is lacking for Hamel's method as far as we know [9]. When considering the radiological results in the literature, we achieved the highest amount of correction and the lowest amount of persistent deformity. We believe that this is based on our exact intraoperative screw adjustment until the TMT-Index is slightly positive assessed fluoroscopically under simulated weight bearing conditions (Fig. 1b). Our principle of slight over correction seems to be useful. A real comparison of outcome scores with the literature is not possible from a scientific point of view because most publications do not report results of a validated score as used in our study [16]. Regarding the pedographic assessment, we could not find any comparable results in the literature. We considered the increase of the midfoot contact area and force as relevant parameters which significantly improved.

We did not perform single stage bilateral screw implantation but implantation at the second side three months after the first operation if indicated following our treatment algorithm (Table 1). This followed the principle that unilateral arthrorisis could also correct the deformity on the contralateral side, and this was observed in 5 of 18 patients (28%) [2–4]. In these patients, bilateral treatment was initially indicated but at 3-month-followup, the indication for the second side was not given any more based on the treatment algorithm (Table 1). This means that the TMT-Index was improved by arthrorisis not only at the operated but also at the contralateral side. The fact that the contralateral foot improves after surgery of the other foot has been reported before and is not surprising [2,3]. There are different attempts for explanations that are mainly based on contralateral reflective muscle activation [2,3]. Vice versa, in the majority of the cases (13 of 18, 73%), the contralateral side did not improve, and arthrorisis was indicated and performed. We did not allow initial full weight bearing as recommended by some authors but 15 kg partial weight bearing was performed [4]. We were concerned that the screw could somehow settle in during the bony healing process which we did not observe at all with partial weight bearing. Growth potential is obligatory for successful arthrorisis [2]. However, the growth does relatively change the position of the screws in relation to the posterior facet as seen in Fig. 2e and f compared with Fig. 2b and c. As shown in Fig. 1a, the screw head is located at the anterior and lateral margin. So even if the screw head is projected further posterior as seen in Fig. 2e and f, it is still at the lateral margin of the joint and not in the joint. We observed a bony trace at the location of the screw heads at followup (Fig. 2e, f, h and i). At the same time, no symptoms such as stiffness or pain were registered as shown by the VAS FA. Consequently, further investigations of this region such as computer tomography (CT) seemed to be not necessary and very debatable regarding the missing symptoms and the radiation contamination. Another concern is a possible loss of correction after implant removal. As recommended we did an implant removal after 2 years and did not register a significant loss of

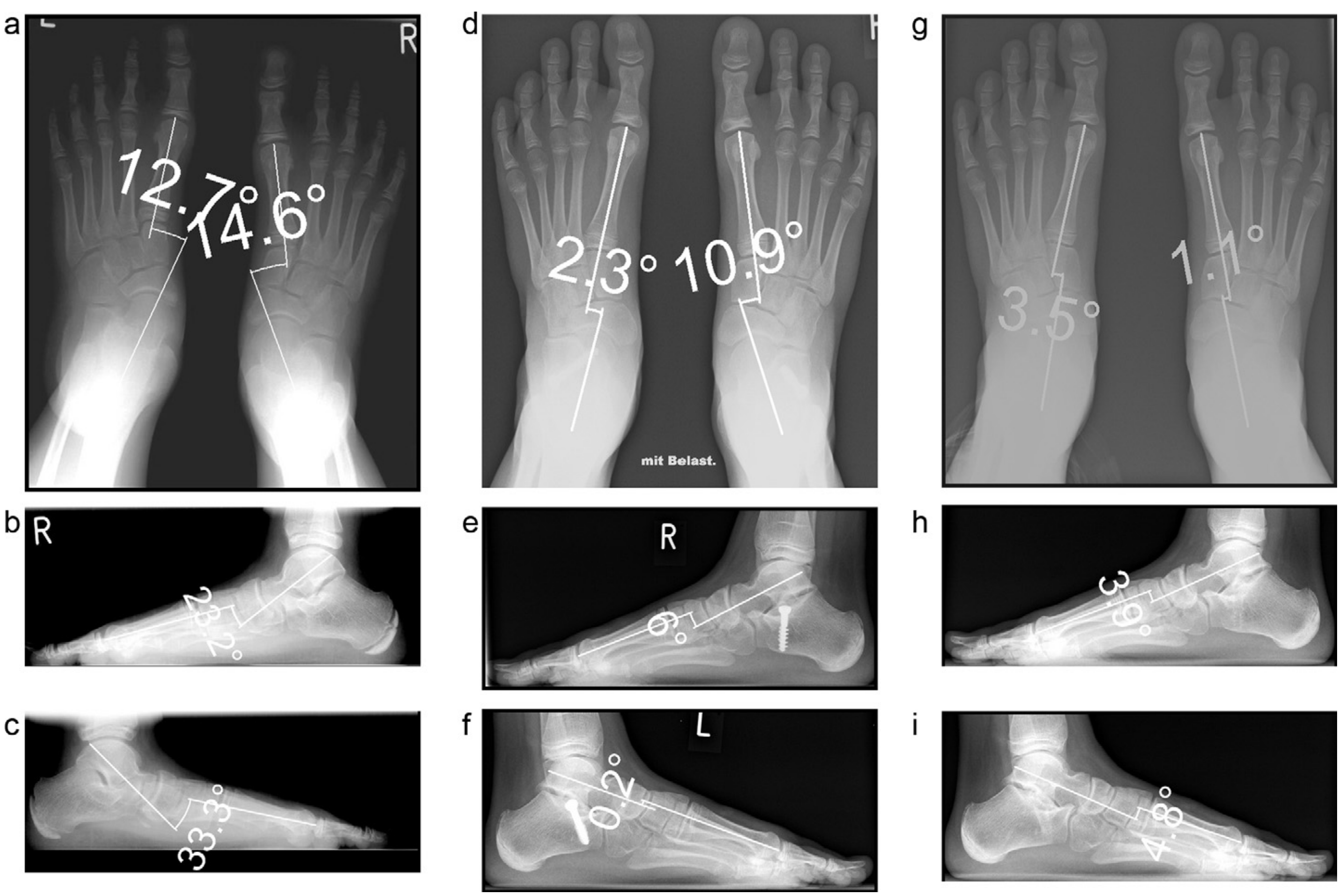

Fig. 2. (a–i) 10-year-old female. Preoperative dorsoplantar TMT angle −14.6°/−12.7° right/left (a) and lateral TMT angle −23.2° right (b), −33.3° left (c) resulting in a TMT-Index of −37.8/−36.0° right/left. At 2-year-followup (with screws), dorsoplantar TMT angle +2.3/−10.9° right/left (d) and lateral TMT angle −6° right (e), +.2° left (f) resulting in a TMT-Index of −3.7°/−10.7° right/left. At 2.5-year-followup (without screws), dorsoplantar TMT angle +3.5/−1.1° right/left (g) and lateral TMT angle −3.9° right (h), −4.8° left (i) resulting in a TMT-Index of −.4/−5.9° right/left. The radiographic measurements were performed with Medicad2 (Hectec, Landshut, Germany).

reduction at followup 6 months later. So why should implant removal be done at all? To leave the screws in vivo is a principal possibility but we were concerned about having the screws close to the posterior facet of the subtalar joint longer than necessary, and we realized that the screws stay very close to that joint despite further growth (compare Fig. 2a–c with Fig. 2d–f). We performed a gastrocnemuis slide in 81% of the cases. Some authors do and others do not recommend this part of the procedure [1–4]. The advantages of releasing the gastrocnemius are a better ankle dorsiflexion and a potentially decreased risk of flatfoot recurrence, and the disadvantages are weakness and potential risk for damaging the sural nerve [1–4]. We decided to perform a gastrocnemius slide if the ankle dorsiflexion with extended knee with screws was less than 10 degrees. Neither sural nerve dysfunction nor weakness was registered, and the flatfoot recurrence rate was zero which could support this principle. However, other factors surely have at least an influence on the recurrence rate which calls this interpretation into question.

The used posterior tibialis tendon insufficiency classification does only assess the function of the posterior tibialis tendon independently from the stiffness of the joints (Table 2). This is different to other less specific classifications [17,18]. We do believe that the function the of the posterior tibialis tendon does not highly correlate with joint stiffness, i.e. there are collapsed flat feet especially in children that are not stiff at all, and vice versa, there are stiff feet without any posterior tibialis tendon insufficiency. In our study, we did not observe any fixed deformities despite the high rate and degree of posterior tendon insufficiency (Tables 2 and 3). Therefore, we would like to emphasize the relevance of our introduced classification which is specific for posterior tendon dysfunction and independent from joint stiffness and/or fixed deformities.

There are some shortcomings of the study such as missing control group, short followup time, and questionable reliability of the radiographic measurements and assessment of posterior tibialis tendon insufficiency. A missing control group is always a methodological shortcoming as in many other studies that we cannot invalidate. The followup time of 2.5 years (6 months after implant removal) for a new technique seems appropriate. Nevertheless a longer followup would be desirable. Especially the followup-time after implant removal seems short (6 months). We did not observe a relevant loss of correction 6 months after implant removal, and we do not believe that later loss of reduction would be likely. This is of course debatable but why should a potential loss of correction occur not immediately after implant removal but later? We cannot answer this important question based on our data. It would be favourable to have longer followup data after implant removal and we are certainly thinking about obtaining that data. Until this data is available, we believe that our existing data adds important information to the literature regarding followup after implant removal. The intra- and interobserver repeatability was sufficient (repeatability coefficients > 0.75) which is important to mention because most studies do not assess this important methodological issue [19]. The measurement of angles on radiographs could be objective as shown by the reported intra- and interobserver reliability. This is possible because angles are independent from the variable magnification factor of radiographs [19]. In contrast, the measurement of distances such as arch height is influenced by the magnification factor of radiographs [19]. Since these magnification factors are highly variable ($\pm 15\%$), an objective measurement is questionable [20]. Therefore, we did not measure distances (for example arch height) but only angles (TMT angles) [19].

In conclusion, all relevant parameters (stage of posterior tibialis insufficiency, TMT-Index, pedographic midfoot contact area and course of gravity center, VAS FA) improved after arthrorisis with calcaneostop screw in pes abductoplanovalgus in children (before and after screw removal). Since the complication rate is very low (zero in our study), this method allows safe and predictable correction.

Conflict of interest

None of the authors or the authors' institution received funding in relation to this study.

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