

Resection of Calcaneonavicular and Talocalcaneal Coalitions With Surgical Correction of the Hindfoot Valgus Deformity in One Step

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Abstract

Background: Calcaneonavicular (CNC) and talocalcaneal (TCC) coalitions are the most common cause of rigid flatfoot in children. After resection, correction of the most frequent valgus-hindfoot deformity usually requires a second-step surgery. We report results of a retrospective study of patients treated with a one-step correction.

Methods: Between 2008 and 2019, data were collected on 26 patients (19 male, 7 female) affected by CNC (n=18) and TCC (n=13), all with rigid symptomatic flatfeet. Average age at surgery was 12.5 ± 1.1 (SD) years (range, 9.8–15.2). All patients (26/26) underwent resection, 20 of 26 underwent at the same time subtalar extraarticular screw arthroereisis (SESA) for correction of residual hindfoot valgus deformity. Pre- and postoperative talocalcaneal angle according to Costa Bartani and Talar inclination angle in weightbearing were measured. Twenty-five of 26 patients had postoperative American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot score.

Results: Pre- and postoperative talocalcaneal average angle for CNC was respectively 141.5 ± 7.7 degrees and 130.5 ± 5.2 degrees ($P < .0001$) and 143.7 ± 7.7 degrees and 129.7 ± 7.0 degrees ($P < .0001$) for TCC. Talar inclination average angle for CNC was 29.2 ± 5.3 degrees and 19.3 ± 1.6 degrees ($P < .0001$) and 31.2 ± 6.4 degrees and 21.4 ± 3.4 degrees ($P < .0001$) for TCC. Average follow-up (FU) was 4.7 ± 3.0 years (range, 6 months–11.9 years, median 4.9 years), with a mean age at FU of 17.2 ± 5.8 (SD) years (min 12.1, max 25.3, median 16.8 years). The mean AOFAS ankle-hindfoot score for CNC and for TCC was 96.6 (range 83–100) for resection and valgus correction as one-step procedure with no statistical difference ($P = .5$) between CNC and TCC. No patients had additional surgery for complications or recurrence.

Conclusion: Symptomatic rigid flatfeet affected by CNC and TCC treated with coalition resection and minimally invasive subtalar arthroereisis (SESA) for residual hindfoot valgus correction in one step in adolescent age achieved good to excellent results in all cases. Further surgery to correct malalignment was avoided.

Level of Evidence: Level IV, retrospective study.

Keywords: flatfoot, rigid flatfoot, tarsal coalitions, surgical correction, subtalar arthroereisis; SESA, calcaneonavicular coalition, talocalcaneal coalition

Introduction

Tarsal coalitions are not a common issue in pediatric orthopaedics but the most frequent cause of rigid flatfoot.¹ All tarsal bones can be involved with calcaneonavicular (CNC) and talocalcaneal (TCC) joints, representing more than 90% of all tarsal coalitions.¹³ The relative incidence of CNC and TCC is 53% and 37%, respectively.³²

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Table 1. Data of Patients Affected by CNC With Preoperative Imaging Performed, Age at Surgery, and Surgical Procedures.⁷

Patient	Gender	Side	Radiograph (AP and LL)	Radiograph (Oblique Projection)	CT	MRI	Age at Surgery (y)	Coalition Resection	SESA
1	M	L	x	x			13.5	x	x
2	M	L	x				12.2	x	x
3	M	L	x	x		x	13.0	x	x
4	M	L	x	x			11.6	x	
5	M	R	x	x		x	12.8	x	x
		L	x	x		x	11.4	x	x
6	M	L	x	x		x	12.3	x	x
		R	x	x		x	13.5	x	x
7	F	R	x				9.8	x	x
8	F	L	x				12.6	x	
9	M	L	x				11.6	x	x
10	M	R	x	x	x	x	14.3	x	x
11	M	L	x	x	x	x	12.9	x	x
12	M	L	x	x		x	12.5	x	
13	M	R	x	x		x	11.5	x	
14	M	R	x	x			13.1	x	x
15	M	L	x	x		x	12.4	x	x
16	M	R	x	x			13.2	x	x

Abbreviations: AP, anteroposterior projection; CNC, calcaneonavicular coalition; CT, computed tomography; LL, laterolateral projection; MRI, magnetic resonance imaging; SESA, subtalar extraarticular screw arthroereisis.⁷

Pain represents a main symptom and is reported in the site of coalition and on the lateral submalleolar region due to hindfoot valgus deformity leading to calcaneal-malleolar impingement.^{31,35} Many authors reported poor surgery outcomes after coalition resection when hindfoot valgus deformity was still present.^{19,34} Other authors reported the need for valgus deformity correction such as calcaneal lengthening osteotomy in a different surgical time, at the onset of foot pain.^{19,24,25} The surgical option to correct hindfoot valgus deformity in adults is usually a subtalar arthrodesis.^{4,20,21} Literature reported a high percentage of failure after only resection procedures if valgus deformity was present.^{19,31,34,35} The hypothesis is that simultaneous correction of valgus deformity in one step could show better outcomes. The aim of this study was to present a surgical approach that considered resection and valgus deformity correction in one step at an adolescent age.

Material and Methods

Between 2008 and 2019, data were collected of 26 patients (19 male, 7 female), all affected by tarsal coalitions and presenting with rigid flatfoot for a total of 31 feet. The study was approved by the competent Authority of the Vita Salute University of San Raffaele Scientific Institute and conducted in accordance with the principles of Good Clinical Practice and the Declaration of Helsinki. The inclusion criteria were rigid painful deformity with talocalcaneal and calcaneonavicular coalitions. The exclusion criteria were

asymptomatic coalitions. Sixteen patients (14 male, 2 female) had a calcaneonavicular coalition (CNC), 2 bilateral (2 male), for a total of 18 feet. Ten patients (6 male, 4 female) had talocalcaneal coalition (TCC), 3 bilateral (2 male, 1 female), for a total of 13 feet.

For clinical evaluation, a hindfoot alignment angle in a standing position^{2,30} and a plantar malleoli view sign (PMVS) in a lying position^{6,7} were used. The heel valgus angle is considered pathological if greater than 10 degrees.² According to the PMVS, an aligned hindfoot should have both the medial and the lateral malleoli visible when seen from a plantar view. When a valgus deformity is present, only the medial malleolus is visible. When a varus deformity is present, only the lateral malleolus is visible.^{6,7}

All patients' feet were evaluated with radiography in weightbearing. Further imaging was performed: 21 oblique radiographic projection (12 CNC, 9 TCC), 7 CT scan (2 CNC, 5 TCC), and 16 MRI scan (10 CNC, 6 TCC) (Tables 1 and 2).

All feet were surgically treated with coalition resection. For hindfoot valgus deformity correction, 25 feet (14 CNC, 11 TCC) underwent subtalar extraarticular screw arthroereisis (SESA)^{6,7} during the same surgical session, whereas in 6 cases (4 CNC, 2 TCC) normal hindfoot alignment was present and SESA was not necessary. Subtalar arthroereisis according to SESA technique is performed by means of a steel half-threaded cancellous screw (3.0 cm length and 4.5 mm and 6.5 mm of thread and head width, respectively) inserted extraarticular at the level of the sinus tarsi, under

Table 2. Data of Patients Affected by TCC With Preoperative Imaging Performed, Age at Surgery, and Surgical Procedures.

Patient	Gender	Side	Radiograph (AP and LL)	Radiograph (Oblique Projection)	CT	MRI	Age at Surgery (y)	Coalition Resection	SESA
1	M	R	x	x	x		12.5	x	x
		L	x	x	x		13.4	x	x
2	M	L	x	x		x	14.4	x	
3	M	L	x				12.2	x	x
4	F	L	x				11.3	x	x
5	M	L	x	x		x	12.4	x	x
6	F	R	x	x		x	10.9	x	x
7	F	R	x				11.8	x	x
		L	x				12.8	x	x
8	M	L	x	x	x		15.1	x	x
9	M	R	x	x	x	x	11.5	x	x
		L	x	x	x	x	12.7	x	x
10*	F	R	x	x		x	11.5	x	

Abbreviations: AP, anteroposterior projection; CT, computed tomography; LL, laterolateral projection; MRI, magnetic resonance imaging; SESA, subtalar extraarticular screw arthroereisis⁷; TCC, talocalcaneal coalition.

*Affected by chromosome 7 deletion.

the lateral talus process and outside the tarsal canal, leaving intact the sinus ligaments. Reaching the inferior calcaneal cortex is not necessary.

The overall mean age at surgery was 12.5 years \pm 1.1 SD (range 9.8-15.2). The mean age of CNC patients was 12.5 years \pm 1.0 SD (range 9.8-14.3), and the mean age of TCC patients was 12.5 years \pm 1.2 SD (range 10.9-15.2).

Talocalcaneal angle according to Costa-Bartani (normal values 120-125 degrees) and talar inclination (normal values 20-30 degrees) angles were radiologically evaluated pre- and postoperatively.²⁹

During follow-up (FU), all patients were evaluated with the AOFAS ankle-hindfoot score divided into 3 main sections and function subgroups. The maximum possible score is 100, and classified as follows: <70=poor, 70 to 79=fair, 80 to 89=good, 90 to 100=excellent.¹⁵

CNC Surgical Procedure

A dorsolateral incision over the calcaneonavicular region and a longitudinal dissection of the extensor digitorum brevis was performed to expose the coalition site.²³ Once mobility of the calcaneonavicular joint was reached after coalition resection, the hindfoot axis was intraoperatively evaluated through the PMVS by observing the position of the hindfoot with respect to the longitudinal axis of the leg: if a foot is properly corrected, both malleoli will be seen from a plantar view. If residual valgus deformity was present, the medial malleolus was visible (positive medial malleolus view sign) and SESA was performed by enlarging the same surgical incisions by 2 cm to reach the sinus tarsi. An immobilization cast was applied for 1 week.⁷

TCC Surgical Procedure

A medial incision was made right under the medial malleolus over the coalition site spanning along the length of the subtalar joint. After identifying the neurovascular bundle, a longitudinal incision was made to open the sheaths of the tibialis posterior and flexor digitorum longus tendons. The tibialis posterior was lifted and the flexor digitorum longus pulled down to expose the coalition site.²³ After coalition resection, foot mobility was clinically tested to evaluate gain in movement.

Hindfoot alignment was evaluated using PMVS.⁷ Among the 13 affected feet, 11 showed a residual valgus deformity. Therefore, lateral incision was made over the sinus tarsi for the SESA procedure.

Statistical Analysis

Mean (\pm SD), range (minimum-maximum), and median were used for descriptive purposes, as appropriate. Comparison between 2 nonparametric independent groups was performed by means of the Mann-Whitney *U* test with 95% CI.

Results

Preoperative clinical evaluation in weightbearing position showed 27 of 31 feet to have valgus hindfoot deformity (hindfoot alignment angle >10 degrees), whereas 4 of 31 feet did not have any deformity. After coalition resection, all feet were intraoperatively evaluated with PMVS: 25 feet (14 CNC, 11 TCC) showed residual hindfoot valgus deformity whereas 6 feet (4 CNC, 2 TCC) showed correct alignment. After SESA, PMVS showed correct alignment of all feet.

At FU, patients filled in the AOFAS ankle-hindfoot score survey. One patient moved to another country and did not respond to the AOFAS questionnaire, with only 6 months of FU unfortunately.

The average FU was 4.7 ± 3.0 (SD) years (range 6 months–11.9 years, median 4.9 years) with a mean age at FU of 17.2 ± 5.8 (SD) years (range 12.1–25.3, median 16.8 years).

Overall results showed an average score of 94.1 and an average score of 96.6 for the 25 feet treated with resection and valgus correction as a one-step procedure.

Results are reported separately for the CNC and TCC groups.

CNC

At preoperative evaluation, patients reported spontaneous pain in the site of coalition in 15 of 18 feet and all reported pain in inversion movements. Fourteen of 18 feet showed residual hindfoot valgus deformity after coalition resection and underwent SESA during the same surgical session. Four of the 18 feet did not show residual valgus intraoperatively and SESA was not performed.

Pre- and postoperative talocalcaneal angle was respectively 141.5 ± 7.6 degrees (SD) and 130.5 ± 5.2 degrees (SD) whereas pre- and postoperative talar inclination angle was respectively 29.2 ± 5.3 degrees (SD) and 19.3 ± 1.6 degrees (SD) with statistical significance ($P < .0001$).

Mean age at FU was 16.6 ± 2.7 (SD) years (range 13.3–25.3, median 16.1 years).

Postoperative AOFAS ankle-hindfoot score for each patient is reported in Table 3. The mean score for the one-step procedure was 97.6, and the average score for the pain, function, and alignment sections were, respectively, 39.2, 48.4, and 10.

Good to excellent results were obtained in all 14 of the 18 feet treated with the one-step procedure. (Figure 1)

At FU, 3 feet were rigid, not showing hindfoot valgus deformity. The one who underwent coalition resection and SESA underwent screw removal after 3 years because of pain. The other two underwent only resection. Two more asymptomatic patients had screw removal after 5.7 and 4.7 years after screw implant, respectively.

TCC

At preoperative evaluation, all were symptomatic. Eleven of 13 showed residual hindfoot valgus deformity after coalition resection and underwent SESA during the same surgical session. Two of 13 feet did not show intraoperatively residual valgus, and SESA was not performed.

Pre- and postoperative talocalcaneal angle was respectively 143.7 ± 7.5 degrees (SD) and 129.7 ± 6.9 degrees (SD) whereas pre- and postoperative talar inclination

angle was respectively 31.2 ± 6.4 degrees (SD) and 21.4 ± 3.4 degrees (SD) with statistical significance ($P < .0001$).

The mean age at FU was 18.0 ± 3.9 (SD) years (range 12.1–24.2, median 18.1 years).

Postoperative AOFAS ankle-hindfoot score for each patient is reported in Table 4. The average score for the one-step procedure was 95.3.

The mean scores for the pain, function, and alignment sections were, respectively, 37, 49.3, and 9.

Good to excellent results were obtained in 11 of 13 feet treated with the one-step procedure (Figure 2). One patient moved to another country having unfortunately only 6 months of FU and did not respond to the AOFAS questionnaire.

At FU, 2 feet were rigid, not showing hindfoot valgus deformity; one underwent coalition resection and SESA whereas the other underwent only coalition resection. No additional surgery was required except in 1 case for removal of SESA screw 5.6 years after the implant.

Two more asymptomatic patients had screw removal after 4 years and 6 years after screw implant, respectively. One patient underwent bilateral simultaneous screw removal after 5 and 6 years, respectively.

AOFAS scores for CNC and TCC were compared using Mann-Whitney *U* test for nonparametric independent groups; no statistical significance was found (P value $< .05$): total $P = .42$, subgroups for pain, $P = .54$; for function, $P = .68$; and for alignment, $P = .20$.

Discussion

Among tarsal coalitions, CNC and TCC are the most frequent, with both leading to symptomatic rigid flatfoot deformity in most of the cases.^{3,11,32}

Pain represents a main symptom, mostly on the site of coalition, and a consensual indication for treatment,²⁴ with resection and fat interposition as gold standard for persistently painful TCC.^{17,33} However, many authors reported poor surgery outcomes after coalition resection when hindfoot valgus deformity remains.^{9,19,24,25} When untreated hindfoot valgus deformity is present, the lateral submalleolar region becomes painful because of calcaneal-malleolar impingement (Figure 3).^{31,35} In one study,³⁴ resection of coalitions with an area at CT $> 50\%$ and heel valgus > 16 degrees showed unsatisfactory results. Other authors reported the need for valgus deformity correction in a different surgical time, at the onset of foot pain. In another study, patients with a coalition area $> 50\%$ or a heel valgus > 21 degrees had still a very satisfactory outcome.¹⁹ However, these patients had to correct the hindfoot deformity, either conservatively with orthoses or surgically with osteotomies or lateral column lengthening. Arthrodesis was used as a salvage procedure.¹⁹

Table 3. AOFAS Evaluation at Follow-up of CNC Patients After Coalition Resection and SESA in One Step.

		Function (Max 50 Points) Subgroups											
Patient	Side	Pain (Max 40 Points)	Activity Limitations, Support Requirements (Max 10 Points)	Maximum Walking Distance, Blocks (Max 5 Points)	Walking Surfaces (Max 5 Points)	Gait Abnormality (Max 8 Points)	Sagittal Motion (Flexion Plus Extension) (Max 8 Points)	Hindfoot Motion (Inversion Plus Eversion) (Max 6 Points)	Ankle-Hindfoot Stability (Anteroposterior, Varus-Valgus) (Max 8 Points)	Overall Function (Max 10 Points)	Alignment (Max 10 Points)	Total	
1	L	30	10	5	5	8	4	6	8	46	10	86	
2	L	40	7	5	3	8	6	6	8	43	10	93	
3	L	40	10	5	5	8	8	6	8	50	10	100	
4 ^a	L	40	10	5	5	8	8	3	8	47	10	97	
5	R	40	10	5	5	8	8	6	8	50	10	100	
6	L	40	10	5	5	8	8	6	8	50	10	100	
7	R	40	10	5	5	8	8	6	8	50	10	100	
8 ^a	L	20	7	4	3	4	8	0	8	34	10	64	
9	L	40	10	5	5	8	8	3	8	48	10	97	
10	R	40	10	5	5	8	8	6	8	50	10	100	
11	L	40	10	5	5	8	8	6	8	50	10	100	
12 ^a	L	30	10	5	5	8	8	6	8	50	5	85	
13 ^a	R	40	10	5	5	8	8	6	8	50	10	100	
14	R	40	10	5	5	8	8	6	8	50	10	100	
15	L	40	10	5	5	8	8	3	8	47	10	97	
16	R	40	10	5	5	8	8	6	8	50	10	100	

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society ankle-hindfoot score; CNC, calcaneonavicular coalition; SESA, subtalar extraarticular screw arthroereisis.⁷
^aSESA not performed.

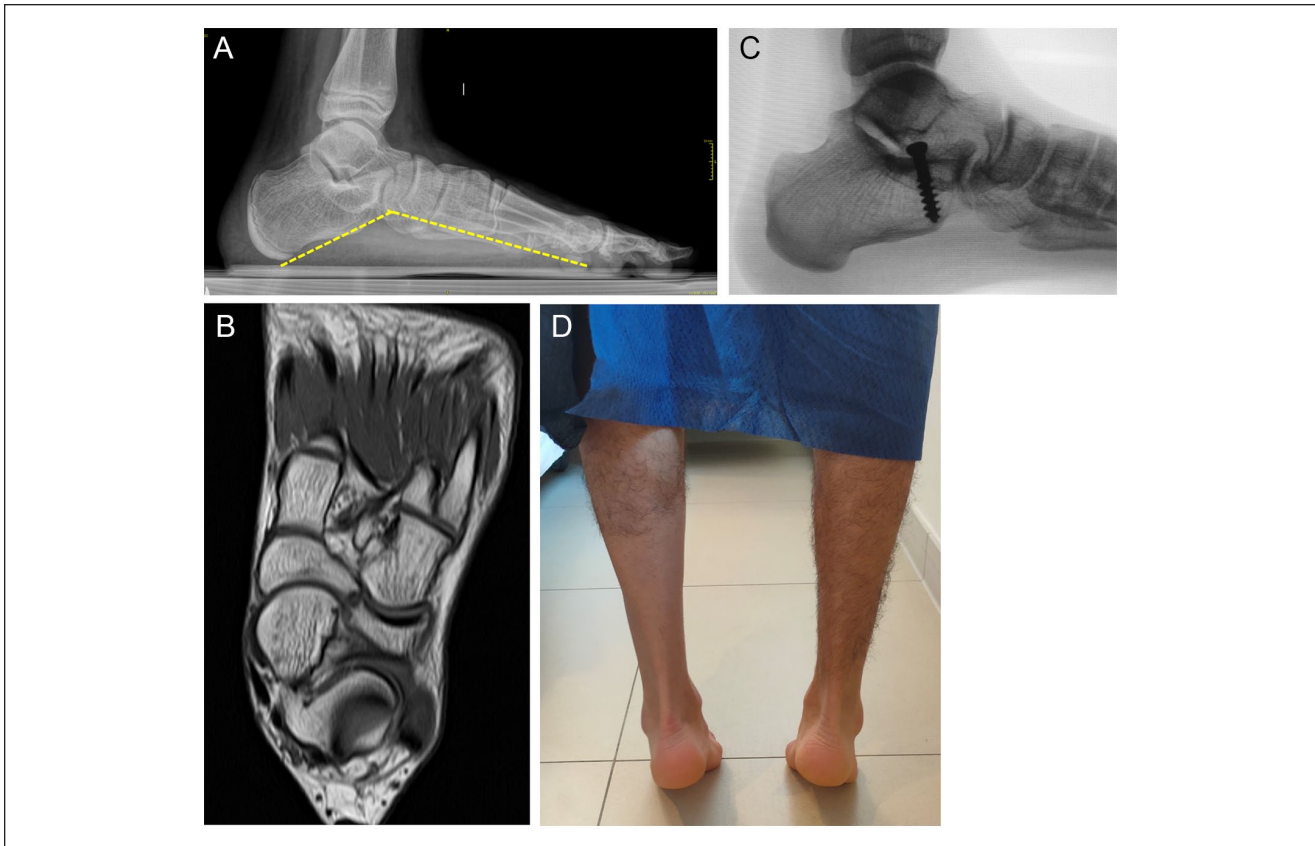


Figure 1. Fourteen-year-old boy affected by symptomatic rigid flatfoot deformity in calcaneonavicular coalition (CNC) of the left foot. (A) Preoperative weightbearing lateral view radiograph with talocalcaneal angle according to Costa Bartani (dashed lines) measuring 136 degrees. (B) Preoperative T1-weighted magnetic resonance imaging showing fibrocartilaginous tissue between the calcaneal and navicular bony border. (C) Radiograph at 6-year follow-up after coalition resection and subtalar extraarticular screw arthroereisis (SESA) procedure for correction of the residual valgus deformity. Proper screw position with normal talocalcaneal angle. (D) Functional outcome in tiptoes with normal pain-free range of motion; right foot for comparison.

Mosca and Bevan²⁴ reported that if there is excessive hindfoot valgus deformity, a valgus correction (calcaneal lengthening osteotomy) with or without a resectable coalition is necessary for pain relief. Also considering CNC, if a valgus deformity is present, an Evans osteotomy or medializing calcaneal osteotomy is suggested in association with the bar resection.³ Recently, an algorithm was proposed for treatment of TCC where the main criteria were: area (on CT scan) of the subtalar posterior facet, degenerative signs in the subtalar joint, and hindfoot valgus.^{17,22} If the area of coalition was less than 50%, with a valgus <16 degrees and no degenerative signs, resection was recommended. If the area was less than 50%, without degenerative signs, with a valgus >16 degrees, resection and realignment surgery was recommended. These data are in accordance with the Mosca and Bevan²⁴ study, where in a severe valgus of the hindfoot, realignment surgery is recommended, without necessarily resection of the bar.

In our study, a surgical approach that considers both resection and valgus deformity correction at adolescent age in one step before joint degenerations appear is presented.

A minimally invasive well-established technique such as SESA was used for valgus correction with excellent radiologic and functional results at an average FU of 4.7 ± 3.0 years and a median FU of 4.9 years.⁶ Talocalcaneal angles showed a statistically significant improvement in the postoperative evaluation. AOFAS scores showed good to excellent results (score >80) for the one-step procedure in all cases in patients with a mean age at FU of 17.2 ± 5.8 (SD) and a median age of 16.8 years. No statistical significance was found between CNC and TCC in AOFAS scores even on analyzing the subgroups (Table 5).

According to the literature, the main indication for subtalar arthroereisis is surgical correction of symptomatic flexible flatfoot. SESA showed a lower percentage of complications (6.38%) in comparison with other techniques.^{6,18} SESA was initially performed for flexible flatfoot at the age of 10.6 ± 1.9 years.⁵ However, in younger patients, after initial correction a recurrence is described.⁵ So the proper age for surgical indication has been postponed and according to our data published later the mean age was 11.5 ± 1.81 years, with only occasional recurrence.⁷ Patients

Table 4. AOFAS Evaluation at Follow-up of TCC Patients After Coalition Resection and SESA in One Step.

Patient	Side	Pain (40 Points)	Activity Limitations, Support Requirements (Max 10 Points)	Maximum Walking Distance, Blocks (Max 5 Points)	Walking Surfaces (Max 5 Points)	Gait Abnormality (Max 8 Points)	Sagittal Motion (Flexion Plus Extension) (Max 8 Points)	Hindfoot Motion (Inversion Plus Eversion) (Max 6 Points)	Ankle-Hindfoot Stability (Anteroposterior, Varus-Valgus) (Max 8 Points)	Overall Function	Alignment (10 Points)	Total
1	R	40	10	5	5	8	8	6	8	50	10	100
	L	30	10	5	5	8	8	6	8	50	10	90
2 ^a	L	30	10	5	5	8	4	3	8	43	10	83
3 ^b	L	40	10	5	5	8	8	6	8	50	10	100
4	L	40	10	5	5	8	8	6	8	50	10	100
5	L	40	10	5	5	8	8	6	8	50	10	100
6	R	40	10	5	5	8	8	6	8	50	10	100
7	R	40	10	5	5	8	8	6	8	50	5	95
	L	40	10	5	5	8	8	6	8	50	5	95
8	L	30	10	5	5	8	8	6	8	50	10	90
9	R	40	10	5	5	8	8	6	8	50	10	100
	L	30	10	5	5	4	8	3	8	43	10	83
10 ^{a,c}	R	40	7	5	5	4	0	0	8	29	5	74

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society ankle-hindfoot score; CNC, calcaneonavicular coalition; SESA, subtalar extraarticular screw arthroereisis⁶; TCC, talocalcaneal coalition.

^aSESA not performed.

^bPatient 3 was not available for further follow-up and AOFAS score.

^cAffected by chromosome 7 deletion.

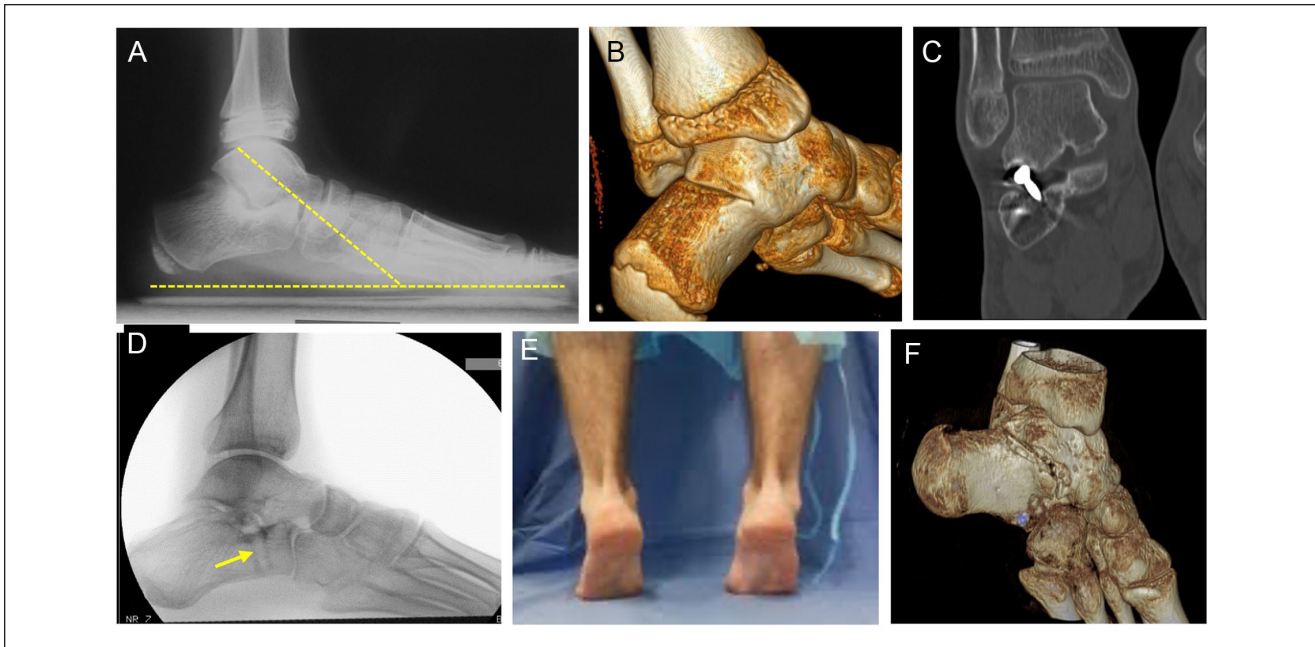


Figure 2. Thirteen-year-old boy affected by talocalcaneal coalition (TCC). (A) Preoperative weightbearing lateral view radiograph showing severe flatfoot deformity with the talar inclination angle (dashed lines) measuring 38 degrees. (B) 3D reconstruction showing a complete osseous coalition. (C) Computed tomography slice at follow-up after coalition resection and subtalar extraarticular screw arthroereisis (SESA) procedure showing screw position under the talus and resection site. (D) Radiograph at 6-year follow-up after coalition resection and SESA procedure in one step and after screw removal (yellow arrow shows screw mark). The correct anatomical talocalcaneal relationship is maintained. (E) Normal hind foot alignment and free subtalar motion in tiptoes standing. (F) 3D reconstruction at follow-up showing the coalition resection site.

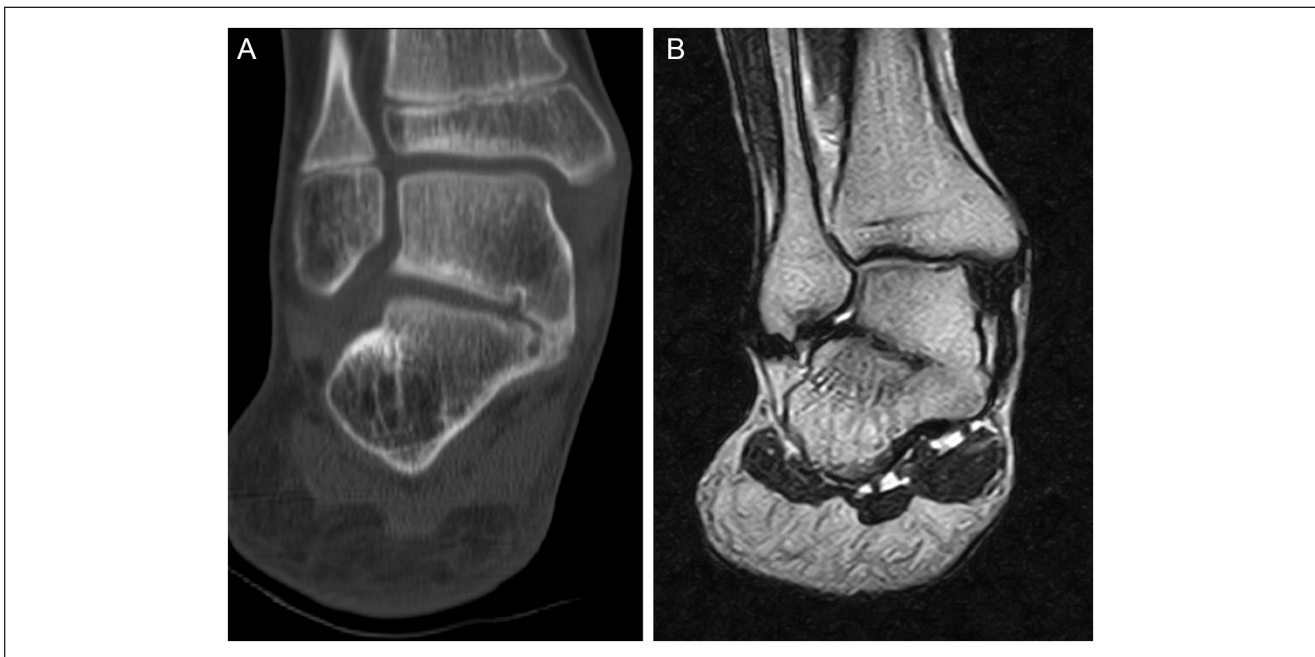


Figure 3. (A) Coronal slice computed tomography scan of the hindfoot in a 12-year-old patient affected by talocalcaneal coalition (TCC) and valgus deformity. (B) For comparison, magnetic resonance imaging slice of an untreated similar type of TCC in a 32-year-old patient with a rigid valgus deformity of the hindfoot complaining of pain laterally for the calcaneofibular impingement; see also arthritis of the subtalar and the ankle joints.

Table 5. Summary of AOFAS Outcomes at FU for Patients' Feet Treated With Coalition Resection and Valgus Correction With SESA as One-Step Procedure.^a

	CNC	TCC	CNC + TCC	P Value: CNC vs TCC
Age at FU, y				
Mean (range)	16.7 (13.3-25.3)	18.4 (13.1-24.2)	17.5 (13.1-25.3)	
Median	16	18.1	17	
Mean AOFAS score				
Total	97.6	95.3	96.6	0.36
Pain	39.2	37	38.3	0.16
Function	48.4	49.3	48.7	0.23
Alignment	10	9	9.5	0.09

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; CNC, calcaneonavicular coalition; SESA, subtalar extraarticular screw arthroereisis; TCC, talocalcaneal coalition.

^aNo statistical significance between CNC and TCC for AOFAS score with subgroups (for $P < .05$, 95% CI).

with rigid flatfoot look for orthopaedic evaluation when they become symptomatic, and this usually happens in older patients because of coalition ossification. In the present study, age at surgery was 12.5 ± 1.1 years (12.5 years in CNC, 12.4 years in TCC).

In tarsal coalition, flatfoot valgus deformity is not flexible. However, after resection of tarsal coalitions when the foot becomes mobile again in the subtalar joint and a severe valgus deformity remains, arthroereisis can be indicated¹⁰ and can follow coalition resection as a one-step procedure.⁹

Only 3 studies have reported few cases of resection and valgus correction in one step. Giannini et al¹⁰ reported resection of TCC and use of a bioabsorbable screw for subtalar arthroereisis (as endorthesis in the subtalar joint) in 12 patients with excellent and good results in 8 (57.1%) and 3 (21.4%) patients respectively. A nonbioabsorbable screw introduced into the talus was used with the aim of obtaining a "calcaneo-stop" effect in association to the TCC resection as described by Di Gennaro et al⁸ in 21 patients with statistically significant AOFAS score improvement postoperatively. Knörr et al¹⁶ reported 4 calcaneo-stop procedures simultaneously performed among 15 patients with symptomatic TCC after arthroscopic resection and a hindfoot valgus >20 degrees, with statistically significant increase in AOFAS score to 90.9 postoperatively.

Twenty of 26 patients of our study, 16 affected by CNC (14 of 18 feet) and 10 TCC (11 of 13 feet), underwent a one-step procedure, combining open resection and SESA. The average postoperative AOFAS ankle-hindfoot score was 96.6, and no patient had recurrency or secondary realignment surgery. Two patients in our study (number 8 of Table 3 affected by CNC and number 10 of Table 4 affected by TCC and chromosome 7 deletion) who had poor and fair outcome per AOFAS scores at FU interestingly did not undergo SESA. Both showed activity

limitation, gait abnormality, no hindfoot motion, but no pain despite abnormal alignment in one case and moderate daily pain with normal alignment in the other case, which was the one with the worst outcome in our study. A mild occasional pain was present despite a normal alignment in 3 of 4 patients with good AOFAS total score, suggesting a coalition-related cause of pain (Tables 3 and 4).

Our study reported outcomes of a new strategy of coalitions treatment that considers hindfoot valgus deformity as the main point for its management. According to our results, arthroereisis (SESA) is a valid alternative procedure for calcaneal osteotomy in adolescents to realign the hindfoot and to avoid arthrodesis in adulthood.

There are many limitations in this study. Preoperative imaging was incomplete, considering CT and MRI. However, when radiographic images clearly demonstrate coalition, only indication for MRI was considered, particularly in CNN, if doubtful or negative radiographic report was present despite the clear findings at clinical examination with pain as a main symptom. CT was more strongly indicated in TCC for surgical planning.

Preoperative AOFAS score was not available for any patient. In addition, midterm, and not long-term, results are reported in this study. Regarding valgus correction with SESA, long-term results are available about this technique, which shows maintaining of hindfoot alignment in flexible flatfeet even after removal of the screw.⁶

The screw removal after subtalar arthroereisis in flexible flatfoot surgical treatment is not frequently described in literature. Some authors describe implant removal as the consequence of a complication; others consider removal also as the last surgical step.⁶

Most of the authors reported screws removal after 2 to 3 years but not before osseous maturity is reached.^{7,12,14,26-28} The clinical and radiographic results are maintained after screw removal.⁶

In the present study, screw removal was not performed routinely. Only 2 patients underwent screw removal due to pain after 3 and 5.6 years, respectively. Five other patients underwent screw removal in asymptomatic feet after a mean time of 5.2 years (range 4-6).

In conclusion, the final goal of surgical treatment of tarsal coalitions is pain relief, maintaining hindfoot alignment after coalition resection. Reasons for preoperative pain in adolescents were more related to coalition, with 15 of 18 feet with spontaneous pain at the site of coalition in CNC and 13 of 13 in TCC. Postoperatively, moderate daily pain was present in 1 of 13 feet affected by TCC despite a normal alignment, suggesting a coalition-related cause of pain. In further 4 feet affected by TCC and in 2 of 18 affected by CNC, mild occasional pain was present, with only 1 with abnormal alignment and all with a good total AOFAS score, not suggesting an alignment issue. Further surgery to correct malalignment seems to be avoided.

Symptomatic rigid flatfeet affected by CNC and TCC can be treated with coalition resection and a minimally invasive SESA for correction of hindfoot valgus in one step at adolescent age. After a median FU of 4.9 years in 20 patients with a median age of 17.5 years achieving good to excellent results in all 25 treated feet, we propose this technique can be considered as a valid treatment option.

Ethical Approval

Ethical approval was not sought for the present study because the study was part of the development of the dissertation entitled "Rigid Flatfoot in Calcaneonavicular and Talo-calcaneal Coalitions: One Step Surgical Treatment in Adolescents" presented by Dr Lorenzo Brogioni, one of the authors of this article. The information provided in this study refers to the above-mentioned dissertation with data of patients treated at the hospital, and which has an exclusive agreement with its university for all dissertations involving its patients.

Declaration of Conflicting Interests

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Supplemental Material

A supplemental video for this article is available online.

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