



## Functional and Radiological Outcomes After Tarsal Coalition Resections: A Minimum 5-Year Follow-Up

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### ABSTRACT

Few studies have evaluated the long-term functional and radiological outcomes of tarsal coalition resections. This study aimed to report and compare the functional and radiological outcomes after talocalcaneal (TC) and calcaneonavicular (CN) coalition resections. Thirty-three patients between 12 and 35 years old with symptomatic tarsal coalitions participated, each undergoing tarsal coalition resections (24 TC and 9 CN). The range of motion, visual analog scale score, American Orthopedic Foot and Ankle Society hindfoot scale, Maryland foot score, tripod index, and modified Kellgren-Lawrence scale for subtalar osteoarthritis were used to evaluate the functional and radiological outcomes. The mean age at the time of surgery and mean follow-up in the TC group were  $17.8 \pm 5.6$  years (range 13 to 35) and  $6.2 \pm 1.7$  years (range 5 to 12), respectively, and  $16.0 \pm 4.4$  years (range 12 to 23) and  $7.7 \pm 3.0$  years (range, 5 to 12) in the CN group. There was no difference in the range of motion, outcome scores, tripod index score, and modified Kellgren-Lawrence scale score between patients in the 2 groups. A positive correlation was noted between the size of the TC coalition, coalition/joint surface ratio, and hindfoot valgus angle regarding outcome scores. However, there was no association between the modified Kellgren-Lawrence scale score and outcome scores. At the minimum 5-year follow-up, the functional and radiological outcomes were similar between TC and CN resections. Subtalar joint osteoarthritis developed in all patients with TC resections and most patients with CN resections, but patients did not have functional impairment.

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Tarsal coalition is a congenital anomaly consisting of osseous, fibrous, or cartilaginous bridging between the tarsal bones (1). It affects ~1% to 2% of the population, with bilaterality in nearly 50% (2). Only 25% of tarsal coalitions are symptomatic (2). Talocalcaneal (TC) and calcaneonavicular (CN) coalitions account for 90% of all tarsal coalitions and typically present at between 10 and 16 years of age (3,4). The symptoms include pain, decreased range of motion, spasm, and frequent foot and ankle injuries (5). Some patients may have associated hindfoot valgus, pes planus, and out-toeing deformities (6). The primary goals in the treatment of tarsal coalitions are pain relief and functional improvement. Conservative treatment is the first-line therapy (7). Surgery is the treatment of choice for patients who have not responded to conservative treatment (8).

The type of operative procedure to perform is controversial. The most frequently performed operative treatment is coalition resection and interposition with muscle, fat, or bone wax (1). The hindfoot alignment and soft tissue conditions must be considered in patients with TC coalitions (1). Previous studies reported that tarsal coalition resections had positive mid- and long-term results (8–13).

However, despite the promising results of surgery, degenerative and foot alignment parameters have not been assessed. This study aimed to report and compare the minimum postoperative 5-year functional and radiological outcomes, including degenerative changes, and foot alignment parameters after TC and CN coalition resections.

### Patients and Methods

After approval from our institutional review board, informed consent was obtained from all participants. Between 2005 and 2012, 64 patients with symptomatic TC and CN coalitions underwent tarsal coalition resection. Patients who had a subtalar or triple arthrodesis, multiple tarsal coalitions or bilateral involvement, any other lower-extremity anomalies, inflammatory arthropathy, neuromuscular conditions, or previous foot and ankle fractures were excluded. After the exclusion criteria were applied, 41 patients were identified. Eight patients did not want to participate in the study, and 33 patients were

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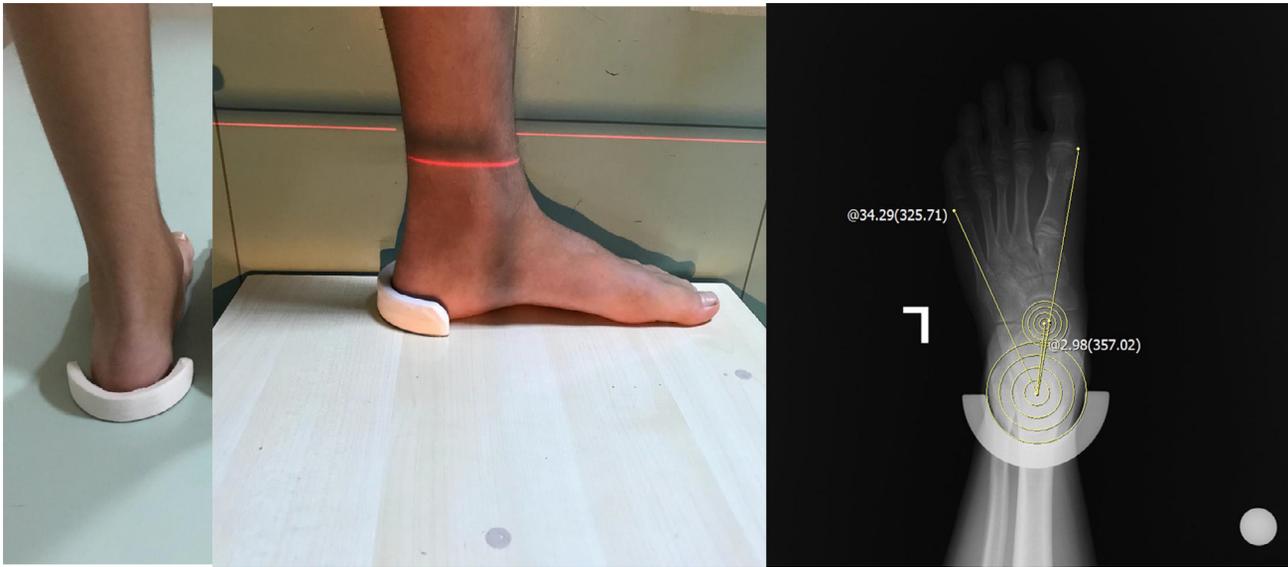


Fig. 1. An example of tripod index X-ray imaging and measurement technique.

enrolled. Twenty-four feet with posterior facet TC and 9 feet with CN coalitions were included. There were 19 males (79.1%) and 5 females (20.9%) in the TC group. In the CN group, there were 7 males (77.8%) and 2 females (23.2%). The age at the time of surgery and follow-up duration were  $17.8 \pm 5.6$  (mean  $\pm$  standard deviation) and  $23.9 \pm 5.7$  years, respectively, in the TC group and  $16.0 \pm 4.4$  and  $23.7 \pm 5.7$  years in the CN group. The patients' records, radiographs, and computed tomography scans were reviewed. Patient demographics, operative procedure notes, and complications were recorded.

Hindfoot valgus and the relative size of the TC coalition concerning the posterior facet was calculated from preoperative computed tomography scans using the technique described by Wilde et al. (14). To determine functional outcomes, we used the visual analog scale (VAS) score postoperatively, American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scale, and Maryland foot score (15–17).

In the clinical examination, ankle plantarflexion, ankle dorsiflexion, subtalar inversion, and subtalar eversion measurements were performed on a table with the patient in the prone position with  $90^\circ$  of knee flexion. Plantarflexion and dorsiflexion were measured as the arch of motion between the line from the first metatarsal head to the heel pad and the long axis of the tibia, as described by Luhmann and Schoenecker (18). Subtalar motion was measured as the arc of motion relative to a line from the long axis of the lower leg as it bisects the Achilles tendon (19).

The tripod index was used to evaluate the foot's alignment radiographically (Fig. 1). The static triangle of support that consists of the center of the heel, first metatarsal head, and fifth metatarsal head is known as the foot tripod (20). The tripod index is a single measurement tool that describes the additive or compensatory effects of deformities at different levels of the foot. It has been used to quantitatively assess standing anteroposterior radiographs using the relationship between the center of the talar head and the foundation of the tripod that is composed of the center of the heel and medial and lateral borders of the forefoot (21). Preoperative and the last follow-up subtalar joint osteoarthritis status were evaluated according to the atlas, based on Kellgren-Lawrence osteoarthritis grading, reported by Kraus et al. (22), by a 6-year experienced orthopedic surgeon (23).

The mean, standard deviation, median, lowest, highest, frequency, and ratio were used in the descriptive data statistics. The distribution of variables was measured with the Kolmogorov-Smirnov test. The Mann-Whitney *U* test was used to analyze independent quantitative data. The chi-squared or Fisher's exact test was used to analyze independent qualitative data. Spearman's correlation analysis was used in the correlation analysis. A *p* value  $<.05$  was considered statistically significant. All statistical analyses were performed using SPSS, version 22.0 (IBM Corp., Armonk, NY).

## Results

The patients' characteristics are summarized in Table 1. The mean preoperative hindfoot valgus angle of TC bars was  $24.8^\circ \pm 6.5^\circ$ . Six patients had  $\leq 16^\circ$  of valgus ( $12.55^\circ \pm 3.61^\circ$ ), and 18 patients had  $>16^\circ$  of valgus ( $27.59^\circ \pm 4.54^\circ$ ). The average ratio of TC bars concerning the posterior facet was  $54.03\% \pm 10.25\%$ ; 10 bars were  $\geq 50\%$  ( $51.41\% \pm 7.13\%$ ), and 11 bars were  $<50\%$  ( $34.74\% \pm 3.89\%$ ).

Regarding the operative technique, in 13 of the 24 TC resections, fat tissue was used as the interposition graft, and bone wax was used in the remaining 11 TC resections. Of the 9 CN resections, fat tissue was used in 5, and bone wax was used in 4. There was no statistically significant differences concerning interposition graft type within or between groups ( $p = .96$ ,  $p = .84$ , and  $p = .94$ ). Concomitant operative procedures included 1 tendo Achilles lengthening procedure and 4 calcaneal lateral column lengthening osteotomies. Three of these patients were in the TC group. One patient underwent bar resection, calcaneal lateral column lengthening osteotomy, and Achilles lengthening; 2 patients underwent bar resection and

Table 1  
Patient characteristics

	Talocalcaneal	Calcaneonavicular	All	<i>p</i>
Number of patients	24	9	33	.015 <sup>*,†</sup>
Age at resection (yr)	$17.8 \pm 5.6$	$16.0 \pm 4.4$	$17.3 \pm 5.1$	.611 <sup>†</sup>
Age at last follow-up (yr)	$23.9 \pm 5.7$	$23.7 \pm 5.7$	$23.8 \pm 5.6$	.887 <sup>†</sup>
Side				.943 <sup>‡</sup>
Right	13	5	18	
Left	11	4	15	
Follow-up (yr)	$6.2 \pm 1.7$ (5 to 12)	$7.7 \pm 3.0$ (5 to 12)	$6.6 \pm 2.2$ (5 to 12)	.138 <sup>†</sup>
Maximum coalition width	$15.7 \pm 4.7$	$15.9 \pm 3.3$	$15.8 \pm 4.3$	.657 <sup>†</sup>
Hindfoot valgus	$16.8 \pm 6.5$	$14.3 \pm 3.5$	$18.2 \pm 6.9$	.020 <sup>*,†</sup>
Coalition/posterior facet ratio	$54.03 \pm 20.25$			
Interposition material				.943 <sup>‡</sup>
Bone wax	11	4	15	
Fat tissue	13	5	18	
Calcaneal osteotomy				1.000 <sup>‡</sup>
Yes	3	1	4	
No	21	8	29	
Tendo Achilles lengthening				1.000 <sup>‡</sup>
Yes	1	0	1	
No	23	9	32	
Postoperative complications				1.000 <sup>‡</sup>
Yes	1	0	1	
No	23	9	32	

Data are n, mean  $\pm$  standard deviation, or mean  $\pm$  standard deviation (range).

\* Statistically significant at  $p < .05$ .

† Significance tested by Mann-Whitney *U* test.

‡ Significance tested by chi-squared test.

**Table 2**

Functional and radiographic outcomes of talocalcaneal and calcaneonavicular resections at the last follow-up (N = 33)

	Talocalcaneal (n = 24)	Calcaneonavicular (n = 9)	p
Visual analog scale	3.1 ± 2.5	2.4 ± 2.6	.453 <sup>†</sup>
AOFAS hindfoot scale	81.5 ± 13.1	82.7 ± 13.0	.855 <sup>†</sup>
Maryland foot score	83.2 ± 13.2	86.6 ± 9.6	.627 <sup>†</sup>
Tripod index	27.1 ± 15.8	27.5 ± 18.5	.903 <sup>‡</sup>
Kellgren-Lawrence grade			.279 <sup>‡</sup>
0	0	3	
1	6	1	
2	8	2	
3	5	3	
4	5	0	

Abbreviation: AOFAS, American Orthopaedic Foot and Ankle Society.

Data are mean ± standard deviation or n.

<sup>†</sup> Significance tested by Mann-Whitney U test.<sup>‡</sup> Significance tested by chi-squared test.

calcaneal lateral column lengthening osteotomy. In the CN group, 1 patient underwent bar resection and calcaneal lengthening osteotomy. As for postoperative complications, 1 patient in the TC group had an early wound infection that was treated with debridement and systemic antibiotics.

Patients who underwent TC resection returned to their activities at a mean of 8.3 ± 2.2 weeks postoperatively. Patients in the CN resection group returned to their activities at a mean of 7.9 ± 2.8 weeks ( $p = .46$ ). There was no significant difference concerning the VAS scores, AOFAS scores, Maryland scores, or tripod indexes in patients in the 2 groups (Table 2; Figs. 2 and 3).

At the final follow-up examination, there was no significant difference in the ankle range of motion in patients in the 2 groups (Table 3). In the TC group, 6 patients (25%) had a modified Kellgren-Lawrence grade of 1, 8 patients (33.4%) had grade 2, 5 (20.8%) had grade 3, and 5 (20.8%) had grade 4 osteoarthritis. In the CN group, 3 patients (33.35%) had a modified Kellgren-Lawrence grade of 0, 1 (11.1%) had grade 1, 2 (22.2%) had grade 2, and 3 (33.35%) had grade 3 subtalar osteoarthritis.

A positive correlation was found between the VAS score and modified Kellgren-Lawrence subtalar osteoarthritis scale, maximum coalition

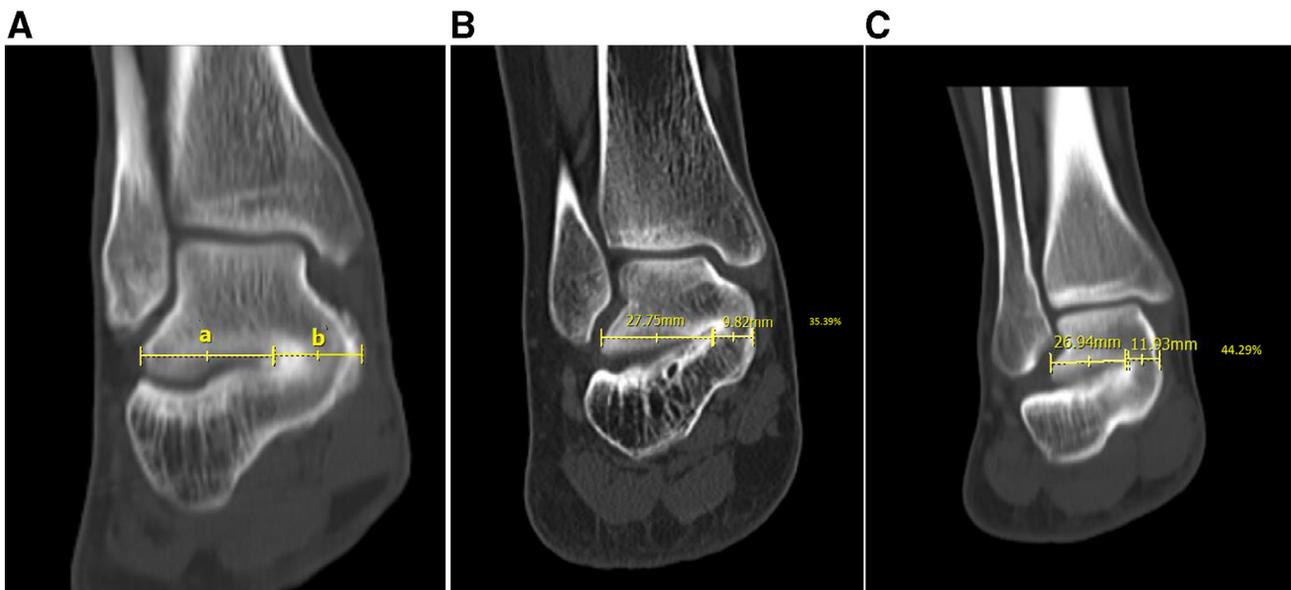
width, and coalition/joint surface ratio ( $r = 0.406$ ,  $r = 0.373$ , and  $r = 0.395$ , respectively) (Table 4). A negative correlation was found between the AOFAS score and maximum coalition width ( $r = -0.506$ ). There was a negative correlation between the Maryland score and modified Kellgren-Lawrence subtalar osteoarthritis scale, maximum coalition width, coalition/joint surface ratio, and preoperative hindfoot valgus angle ( $r = -0.403$ ,  $r = -0.508$ ,  $r = -0.366$ , and  $r = -0.458$ , respectively). The modified Kellgren-Lawrence subtalar osteoarthritis scale was positively correlated with the coalition/joint surface ratio ( $r = 0.422$ ). No correlation was found between the VAS score, AOFAS score, Maryland score, or modified Kellgren-Lawrence subtalar osteoarthritis scale and the tripod index ( $r = -0.017$ ,  $r = -0.021$ ,  $r = 0.014$  and  $r = -0.294$ , respectively).

Patients with TC coalitions with hindfoot valgus that was  $\leq 16^\circ$  had significantly more favorable outcomes than did those with TC coalitions with hindfoot valgus  $> 16^\circ$  (VAS score, 1.5 ± 2.4 versus 3.8 ± 2.2,  $p = .015$ ; AOFAS score, 85.9 ± 14.2 versus 79.5 ± 11.7,  $p = .041$ ; Maryland score, 87.5 ± 15.2 versus 82.1 ± 10.2,  $p = .033$ ) (Table 5). Additionally, patients with TC coalitions with a coalition/joint surface ratio that was  $< 50\%$  had significantly more favorable outcomes than did those with a ratio  $\geq 50\%$  (VAS score, 2.3 ± 2.6 versus 4.4 ± 1.8,  $p = .041$ ; AOFAS score, 84.7 ± 13.5 versus 76.1 ± 10.9,  $p = .045$ ; Maryland score, 86.5 ± 12.3 versus 77.7 ± 13.5,  $p = .034$ ) (Table 6). There was no difference between hindfoot valgus that was greater or less than  $16^\circ$  and a coalition/joint surface that was greater or less than 50% concerning the Kellgren-Lawrence subtalar osteoarthritis grade ( $p = .063$  and  $p = .224$ , respectively).

## Discussion

The most important findings of our study were that more favorable outcomes were noted in the long term when TC coalitions were  $< 50\%$  of the posterior facet, hindfoot valgus was  $\leq 16^\circ$ , and coalitions were  $< 15$  mm in width. Our findings are compatible with those of previous reports (9–14,24).

In previous studies, good to excellent clinical and functional results were obtained after coalition resection and interposition grafting, even in patients with subtalar arthritis. This is important, because all patients were at a quite active age. However, most of these studies had a



**Fig. 2.** (A) Measurement technique of the maximum width of the coalition (b) and the posterior facet (a). Percentage of involvement was measured as  $b/a \times 100$ . (B, C) Patient examples demonstrating the extent of the subtalar coalition.

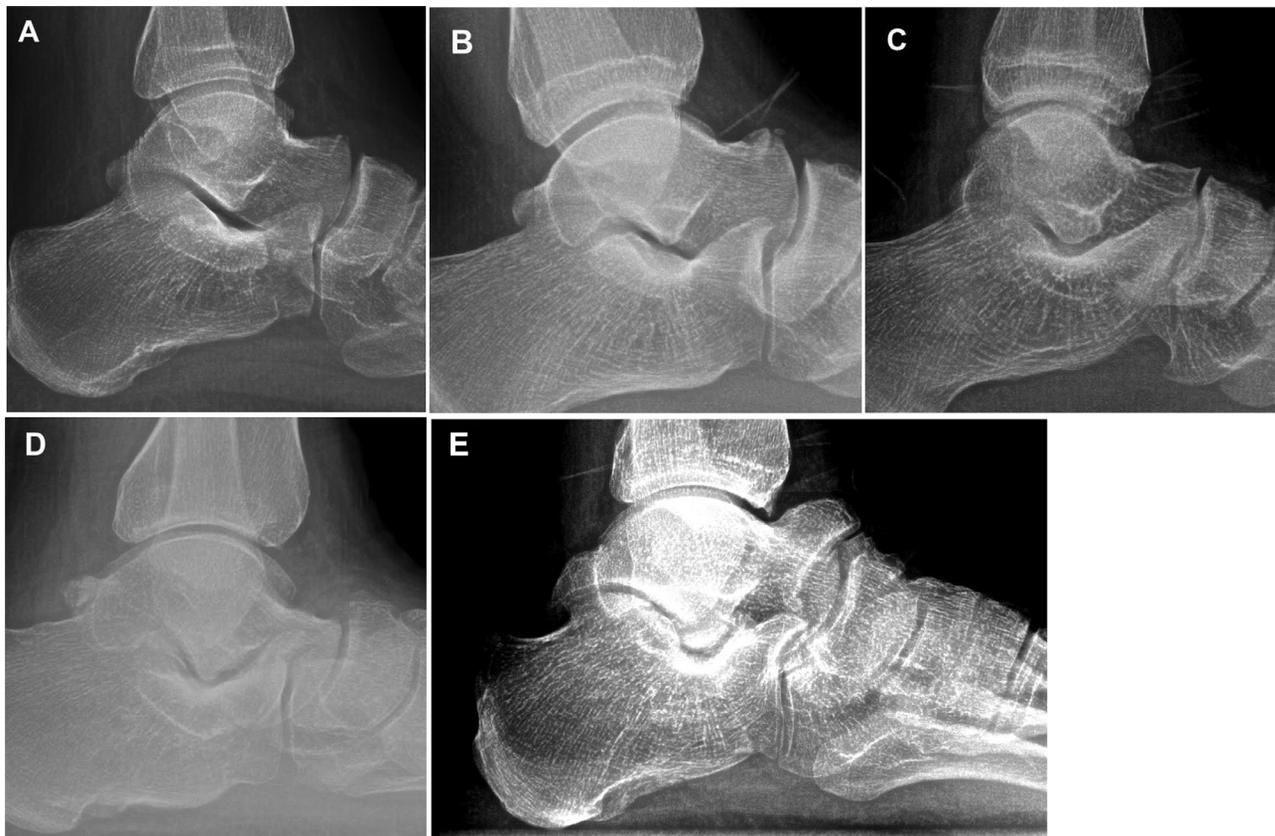


Fig. 3. Modified Kellgren-Lawrence subtalar osteoarthritis classification examples, A (grade 0) to E (grade 4).

relatively short follow-up periods or a long follow-up period with only functional and clinical outcome results (8–13).

In a long-term follow-up study, Khoshbin et al. (8) reported similar functional outcomes and pain between TC and CN resections. Our results are compatible with those of Khoshbin et al. Furthermore, return to activity, foot alignment, and osteoarthritic changes were found to be similar between CN and TC coalition resections (8).

Worse outcomes were reported with coalitions that were  $\geq 50\%$  in size, whereas Khoshbin et al. (8) reported that coalition resections  $\geq 50\%$  of the surface area had excellent long-term functional outcomes (7,18). In our study, better functional results were obtained in resections that were  $< 50\%$  of the surface area. We think the cutoff value of 50% of the

surface area is convenient for clinical use, although it was arbitrarily established. However, our results do not suggest that arthrodesis should be used as first-line therapy for TC coalitions  $\geq 50\%$ , because no significant difference was found concerning subtalar osteoarthritis between coalitions that were greater and less than 50%. Patients had minimal pain with good functional outcomes, despite having subtalar osteoarthritis. Arthrodesis leads to stress transfer to the adjacent joints in the long term (25). However, arthrodesis is an option in the future, if needed.

Hetsroni et al. (26) reported increased loading and torque in the subtalar and adjacent joints after tarsal coalition resection. They concluded that increased loading and torque might promote articular degeneration in the long term (26). Skwara et al. (27) noted abnormal gait and foot loading after resection and resection interposition procedures. Our results support theirs. All patients in both groups developed subtalar osteoarthritis to varying degrees. New strategies may be needed to avoid degenerative changes.

Previously, the incidence of reoperations after the tarsal coalition was reported to be low. In a long-term study, Khoshbin et al. (28) noted that  $> 85\%$  of their patients never required additional operations. In our study, 3 patients (9.1%) needed an additional procedure. One patient in the TC resection group and 2 in the CN resection group underwent triple arthrodesis at a minimum of 3 years postoperatively.

The treatment of valgus deformities is as important as resection of the coalition. Calcaneal lengthening osteotomy with gastrocnemius or Achilles tendon lengthening is an effective method to correct the valgus deformity and relieve pain (3). In our study, 3 patients in the TC resection group and 1 in the CN resection group underwent calcaneal lengthening osteotomy. All 4 patients had  $> 25$  degrees of hindfoot valgus. One patient in the TC resection group underwent an additional Achilles tendon lengthening procedure due to gastrocnemius contracture.

Table 3

Preoperative and postoperative physical examination measurements of talocalcaneal and calcaneonavicular resections

	Talocalcaneal	Calcaneonavicular	<i>p</i>	All Patients
Ankle dorsiflexion				
Preoperative	12.8 ± 3.0	13.7 ± 1.9	.273	13.1 ± 2.7
Postoperative	10.9 ± 2.7	13.1 ± 2.6	.071	11.5 ± 2.8
Ankle plantar flexion				
Preoperative	26.9 ± 5.8	25.7 ± 5.5	.696	26.6 ± 5.6
Postoperative	24.1 ± 5.7	25.1 ± 5.0	.507	24.4 ± 5.5
Subtalar inversion				
Preoperative	8.1 ± 2.0	8.8 ± 1.2	.344	8.3 ± 1.8
Postoperative	6.7 ± 2.7	7.9 ± 2.8	.278	7.0 ± 2.8
Subtalar eversion				
Preoperative	4.9 ± 2.5	6.2 ± 1.6	.169	5.2 ± 2.4
Postoperative	4.3 ± 3.3	5.1 ± 3.2	.526	4.5 ± 3.3

Data are mean ± standard deviation.  
Significance tested by Mann-Whitney *U* test.

**Table 4**  
Spearman correlation analysis results (N = 33)

	AOFAS Hindfoot Score	Maryland Foot Score	Modified Kellgren-Lawrence Subtalar Osteoarthritis Grade	Maximum Coalition Width	Coalition/Joint Surface Ratio (%)	Hindfoot Valgus Angle	Tripod Index
VAS score							
<i>r</i>	−0.856	−0.839	0.406	0.373	0.395	0.384	−0.017
<i>p</i>	.000*	.000*	.019*	.033*	.023*	.064	.927
AOFAS hindfoot score							
<i>r</i>		0.901	−0.299	−0.506	−0.337	−0.430	−0.021
<i>p</i>		.000*	.090	.003*	.055	.036	.909
Maryland foot score							
<i>r</i>			−0.403	−0.508	−0.366	−0.458	0.014
<i>p</i>			.020*	.003*	.036*	.025*	.938
Modified Kellgren-Lawrence subtalar osteoarthritis grade							
<i>r</i>				0.280	0.422	0.162	−0.294
<i>p</i>				.114	.014*	.449	.097

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale.

\*Statistically significant at  $p < .05$ .**Table 5**  
Comparison of functional outcome scores and subtalar osteoarthritis grades between pre-operative hindfoot valgus of  $\leq 16^\circ$  and  $> 16^\circ$  (N = 33)

	Hindfoot Valgus $\leq 16^\circ$	Hindfoot Valgus $> 16^\circ$	<i>p</i>
VAS	1.5 ± 2.4	3.8 ± 2.2	0.015* <sup>†</sup>
AOFAS hindfoot scale	85.9 ± 14.2	79.5 ± 11.7	0.041* <sup>†</sup>
Maryland foot score	87.5 ± 15.2	82.1 ± 10.2	0.033* <sup>†</sup>
Kellgren-Lawrence grade			
0	3	0	0.063 <sup>‡</sup>
1	3	4	
2	1	9	
3	4	4	
4	1	4	

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale.

Data are mean ± standard deviation or n.

\* Statistically significant at  $p < .05$ .† Significance tested by Mann-Whitney *U* test.

‡ Significance tested by chi-squared test.

This study has strengths and limitations. This is the first study to evaluate degenerative changes and tripod alignment after tarsal coalition resection. We used validated outcome scores, quantitatively measured foot alignment parameters, and evaluated osteoarthritic changes at the last follow-up examination. However, the limitations of the study include its retrospective nature, lack of preoperative functional

**Table 6**  
Comparison of functional outcome scores and subtalar osteoarthritis grades between coalition/joint surface ratio of  $< 50\%$  and  $\geq 50\%$  (N = 33)

	Coalition/Joint Surface Ratio $< 50\%$	Coalition/Joint Surface Ratio $\geq 50\%$	<i>p</i>
VAS	2.3 ± 2.6	4.4 ± 1.8	0.041* <sup>†</sup>
AOFAS hindfoot scale	84.7 ± 13.5	76.1 ± 10.9	0.045* <sup>†</sup>
Maryland foot score	86.5 ± 12.3	77.7 ± 13.5	0.034* <sup>†</sup>
Kellgren-Lawrence grade			
0	0	0	0.224 <sup>‡</sup>
1	5	1	
2	6	2	
3	2	3	
4	2	3	

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale.

Data are mean ± standard deviation or n.

\* Statistically significant at  $p < .05$ .† Significance tested by Mann-Whitney *U* test.

‡ Significance tested by chi-squared test.

outcome scores, and a relatively low number of patients. Moreover, a sample size calculation before the study was not done. Our patient population included both pediatric and adult patients. No significant difference was noted in the functional and radiological outcomes of pediatric and adult patients. Further prospective studies are needed.

In conclusion, the functional and radiological outcomes of TC and CN coalition resections are similar in the long term. Favorable outcomes are obtained despite various degrees of subtalar osteoarthritis.

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