Bilateral Single-stage Middle Facet Talocalcaneal Coalition Resection Combined with Flatfoot Reconstruction: A Report of 3 Cases and Review of the Literature. Investigations Involving Middle Facet Coalitions—Part 1

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Talocalcaneal middle facet coalitions are associated with rigid pes planovalgus that often requires surgical intervention. Simple resection of the coalition is preferred for symptomatic cases in the absence of rearfoot arthritis. While resection of the coalition will remove the osseous restriction of motion and may eliminate pain, the procedure does not specifically correct the concomitant pes planovalgus. In this report of 6 feet in 3 patients, we advocate combining resection of the coalition with concomitant flatfoot reconstruction in a single-stage operation. The patients in this series averaged 13.67 (range 12–17) years of age at the time of their foot surgeries, and their follow-up averaged 30 (range 16–54) months. All of the patients displayed bilateral middle facet talocalcaneal coalitions and underwent bilateral resection combined with flatfoot reconstruction. Each patient had 1 foot corrected followed by a period of at least 6 months before the contralateral foot was corrected. The mean postoperative American Orthopaedic Foot and Ankle Society ankle-hindfoot score was excellent (94.33 ± 2.81 points) overall. The median radiographic values for calcaneal inclination, Meary's, and anteroposterior talar-first metatarsal angles demonstrated statistically significant improvements: 9° (3°, 13°) (P = .0273), 4° (2°, 7°) (P = .0269), and 6° (3°, 11°) (P = .0277), respectively, and all feet demonstrated improved subtalar joint motion without pain. Although long-term results remain to be determined in a larger cohort, it is hoped that this combined approach to talocalcaneal coalition will delay or obviate future rearfoot arthrosis and the need for arthrodesis. Level of Clinical Evidence: 4. (The Journal of Foot & Ankle Surgery 47(3):180–190, 2008)

Key words: flatfoot reconstruction, middle talocalcaneal facet, pes planus, tarsal coalition

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Traditional surgical management of symptomatic middle facet tarsal coalition involves either resection of the coalition or rearfoot arthrodesis (1–4). There are no exact guidelines that direct the surgeon when to select arthrodesis over reconstruction. It is generally thought that resection of the coalition is preferred in a younger patient who has not developed compensatory arthrosis of the rearfoot complex, though fusion may be considered when the pes planus is significant in the absence of arthrosis (1–4). While simple resection of the coalition may eliminate pain and restore rearfoot motion, it does not address the associated pes planovalgus and ankle equinus deformities. Interestingly, two separate studies attributed poor results following simple resection with severe heel valgus, suggesting that pes planovalgus may be part of the pathologic pain process associated with coalition (5, 6). Moreover, there are no long-term cohort studies that indicate that resection of a tarsal coalition will resolve peroneal spasm, restore rearfoot motion, or enable the pes planus deformity to correct itself over time.

Although other surgeons have touched on the concept of treating the concomitant deformity of pes planovalgus in association with resection of middle facet talocalcaneal coalitions, the concept has yet to be fully explored (6–12). Cain and Hyman (7) corrected the calcaneal valgus without coalition resection by performing medial closing wedge calcaneal osteotomies in a series of patients, in an attempt to alleviate symptoms and avoid fusion. Westberry et al (6) combined radical sustentaculum tali excision with lateral column lengthening by means of calcaneocuboid distraction arthrodesis in 2 feet, and identified residual pes planus as a probable reason for failure of isolated resection of the tarsal coalition. Lepow and Richman (13) and Downey (9) separately reported on coalition resection along with subtalar arthroereisis, in 1988 and 2001, respectively. More recently, Giannini and colleagues (11) performed coalition resection with subtalar arthroereisis with a bioreabsorbable implant in 14 feet. In this report, we present our preliminary experience with single-stage middle facet tarsal coalition resection combined with flatfoot reconstruction in 3 patients, all of whom underwent bilateral reconstruction one foot at a time.

Patients and Methods

We reviewed the medical charts and radiographs of consecutive adolescent patients who suffered from bilateral middle facet talocalcaneal coalitions with concomitant pes planovalgus and ankle equinus deformities. Each patient presented with a complaint of painful flatfeet with diffuse rearfoot pain that affected their normal activities. In all cases, there was no pain with talonavicular or ankle joint range of motion, whereas the subtalar joint was distinctly painful to direct efforts at manipulation without grossly appreciable range of motion. In each case, weight-bearing plain film radiographs and axial computerized tomography (CT) were used to further evaluate and confirm the presence and extent of the middle facet talocalcaneal coalition, evaluate the posterior facet for the presence of subtalar arthritis, and to confirm the absence of significant arthritic changes in adjacent joints. In regard to each foot, the patients had failed an initial nonoperative treatment course consisting of nonsteroidal anti-inflammatory drugs, biomechanical foot orthotics, and/or cast immobilization.

From December of 2002 through June of 2006, each of the painfully deformed feet was reconstructed by one of the senior authors (N.M.B. or S.M.R.), one foot at a time. An interval of at least 6 months was allowed to pass before subsequent surgical intervention was undertaken on each patient's contralateral foot. In all cases, the surgical technique entailed the use of a single-stage resection of the middle facet talocalcaneal coalition performed in conjunction with flatfoot reconstruction involving a combination of the following procedures: Evans calcaneal osteotomy, medializing calcaneal osteotomy, medial column fusion, tendoAchilles lengthening, gastrocnemius recession, and/or flexor digitorum longus transfer to the posterior tibialis

Table 1 Demographic variables describing the case series

Patient	Surgeon	Age,* y, mo	Foot	Type	Procedures	Postoperative AOFAS hindfoot-ankle score	Follow-up duration, mo
LL	NMB	12, 4	Right	F	TAL, MFCR, Evans	92	22
LL	NMB	12, 10	Left	O	TAL, MFCR, Evans	90	16
BW	NMB	16, 8	Right	O	TAL, MFCR, MCO, NC fusion, FDL to PT	97	28
BW	NMB	17, 8	Left	F	TAL, MFCR, MCO	97	16
GK	SMR	12, 5	Left	O	GIAR, MFCR, NC fusion, Evans	95	54
GK	SMR	13, 5	Right	O	GIAR, MFCR, NC fusion, Evans	95	42

Abbreviations: O, osseous; F, fibrous; MFCR, middle facet coalition resection; MCO, medializing calcaneal osteotomy; NC, naviculocuneiform; FDL, flexor digitorum longus; PT, posterior tibialis; GIAR, gastrocnemius intramuscular aponeurotic recession; TAL, tendoAchilles lenthening.

*Age at time of surgery.

Table 2 Radiographic measurements describing the case series

Patient	Preoperative radiographic angle measurements (°)			Postoperative radiographic angle measurements (°)		
	Calcaneal inclination	Meary's	Talar-first metatarsal	Calcaneal inclination	Meary's	Talar-first metatarsal
LL	1	8	11	10	4	7
LL	0	8	18	13	6	8
BW	6	8	4	16	1	1
BW	9	2	5	18	0	0
GK	11	9	8	15	3	1
GK	11	8	12	14	4	1
Mean ± SD	6.33 ± 4.89	7.17 ± 2.56	9.67 ± 5.16	14.33 ± 2.73	3 ± 2.19	3 ± 3.52
Median (range)	7.5 (0, 11)	8 (2, 9)	9.5 (4, 18)	14.5 (10, 18)	3.5 (0, 6)	1 (0, 8)

tendon. The precise combination of procedures was determined at the discretion of the operating surgeon. In all of the cases, however, a standard surgical scheme was followed. This included correction of the ankle equinus deformity, after which an incision was made over the sustentaculum tali for resection of the middle facet coalition. Following resection of the coalition, bone wax (Ethicon, Johnson & Johnson, Somerville, NJ) was applied to the resultant bleeding bony surfaces and previously harvested autogenous tissue (superficial fascia and subcutaneous fat), or additional bone wax, was interposed between the resected surfaces. Upon completion of the resection of the middle facet, additional flatfoot reconstruction was undertaken in accordance with the planal dominance of the flatfoot deformity, the presence or absence of an open calcaneal apophysis, and the degree of naviculocuneiform (NC) sag and/or posterior tibialis dysfunction. In skeletally mature (defined as ≥16 years of age, for the purposes of this investigation) patients with heel valgus, a medializing calcaneal osteotomy was used to correct the calcaneal valgus. This particular procedure was performed through a lateral incision, and the osteotomy was fixated with 2 percutaneously placed 6.5-mm partially threaded interfragmental compression screws. In skeletally immature (<16 years of age) patients with an associated transverse plane dominant flatfoot deformity, an Evans calcaneal osteotomy was performed using tricortical iliac crest allograft that was fixated with either a buttress plate or a single 3.5-mm cortical screw. Intraoperative fluoroscopic image intensification was used to assess the degree of realignment of the hindfoot in all of the cases. If naviculocuneiform joint sag was noted on the preoperative clinical and radiographic assessments, then an NC fusion was performed once the more proximal architecture had been addressed. Following the operation, in all of the cases, the reconstructed foot was immobilized in a short-leg non–weight-bearing cast for 4 to 6 weeks. After removal of the cast, in all of the cases, physical therapy involving subtalar joint range of motion and triceps surae exercises was initiated. The postoperative weight-bearing status was dictated by the radiographic evidence of osteotomy and/or fusion healing, defined as the presence of calcified trabeculae traversing the osseous interface on the postoperative foot radiographs.

Postoperatively, objective and subjective assessments were obtained using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scoring system at the most recent follow-up (14). Furthermore, in addition, the following radiographic angles were obtained from the

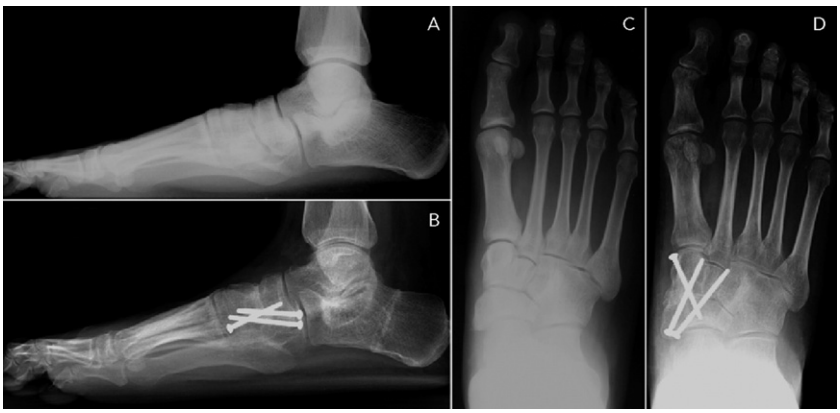

FIGURE 1 Weight-bearing preoperative @0017 and postoperative radiographs of patient BW right foot—surgery performed was middle facet talocalcaneal coalition resection and flatfoot reconstruction (tendo-Achilles lengthening, medializing calcaneal osteotomy, naviculocuneiform joint fusion, posterior tibialis tendon transfer/augmentation with flexor digitorum longus). Preoperative lateral (A), postoperative lateral (B), preoperative anteroposterior (C), and postoperative anteroposterior (D).

FIGURE 2 Weight-bearing preoperative and postoperative radiographs of patient GK right foot—surgery performed was middle facet talocalcaneal coalition resection and flatfoot reconstruction (gastrocnemius intramuscular aponeurotic recession, Evans calcaneal osteotomy, naviculocuneiform joint fusion). Preoperative lateral (A), postoperative lateral (B), preoperative anteroposterior (C), and postoperative anteroposterior (D).

weight-bearing postoperative films and compared to the preoperative values: calcaneal inclination angle, Meary's, and the anteroposterior (AP) talar-first metatarsal angles. All of the plain film radiographic measurements were determined by the same investigator (K.J.K.), and statistically significant differences between the measurements were calculated using the Wilcoxon signed ranks test, with statistical significance being defined at the 5% level.

Results

The patient demographic variables are presented in Table 1, and the radiographic measurements are depicted in Table 2. The weight-bearing radiographic images are displayed in Figures 1 to 4. Radiographically, each foot demonstrated dorsolateral peritalar subluxation and low calcaneal inclination in the preoperative period. One of the patients (BW) had difficulty performing a single leg heel rise on her right lower extremity, a preoperative clinical finding that was suggestive of posterior tibialis insufficiency in the preoperative period. From December of 2002 through June of 2006, each of the painfully deformed feet was reconstructed by one of the senior authors (N.M.B. or S.M.R.), one foot at a time. In patients BW and LL, a Z-lengthening of the Achilles tendon was completed with or without harvesting the plantaris tendon and/or subcutaneous fat through the same incision for later placement into the resected coalition site. Patient GK underwent gastrocnemius intramuscular aponeurotic recessions (15). Previously procured autogenous soft tissues (superficial fascia and subcutaneous fat) as well as bone wax were used in patients BW and LL, whereas bone wax alone was used in the patient GK. A medializing calcaneal osteotomy (MCO) was used to correct calcaneal valgus in 2 feet, whereas the Evans calcaneal osteotomy was used in 4 of the feet treated in this series. An NC fusion was performed once the more proximal architecture had been addressed in 3 feet; and, in one patient (BW, right foot), the NC fusion was combined with a flexor digitorum longus tendon transfer to the posterior tibialis tendon for tibialis posterior insufficiency, as this patient had an attenuated posterior tibialis tendon that was identified at the time of surgery. Intraoperative fluoroscopic image intensification revealed improved pedal architecture, with reduced cuboid abduction, in all of the cases. During the postoperative period, the patients' weight-bearing status was dictated by the radiographic evidence of osteotomy and/or fusion healing, and was initiated at 6 weeks following the surgery in all of the cases. In the case of patient BW with the right-sided

FIGURE 3 Weight-bearing preoperative and postoperative radiographs of patient LL left foot—surgery performed was middle facet talocalcaneal coalition resection and flatfoot reconstruction (tendo-Achilles lengthening, Evans calcaneal osteotomy). Preoperative lateral (A), postoperative lateral (B), preoperative anteroposterior (C), and postoperative anteroposterior (D).

FIGURE 4 Clinical weight-bearing images of patient LL, before (A & B) and after (C & D) single-stage middle facet talocalcaneal coalition resection combined with flatfoot reconstruction.

MCO, the retained hardware became symptomatic and required removal approximately 4 months after the index operation. Removal of the hardware resulted in resolution of this particular patient's symptoms.

The mean postoperative AOFAS ankle-hindfoot score was 94.33 ± 2.81 points, a 100-point clinical subjective and objective scoring scale. By convention, the AOFAS scale scores were categorized as excellent (90 to 100 points), good (80 to 89 points), fair (70 to 79 points), or poor (less than 70 points) (14, 16). Hence, all 6 of the feet described in this report had excellent postoperative results. Median radiographic values for calcaneal inclination, Meary's, and AP talar-first metatarsal angles demonstrated statistically significant improvement: 9° (3°, 13°) ($P = .0273$), 4° (2°, 7°) ($P = .0269$), and 6° (3°, 11°) ($P = .0277$), respectively (Table 3).

Postoperatively, there was a clinically significant relief of preoperative symptoms and the subtalar joint exhibited painless range of motion upon direct manipulation. Radiographs demonstrated improvement in the calcaneal inclination, Meary's, and the talar-first metatarsal angles, and there was no evidence of recurrence of the coalition after the index operation in all of the patients. Following healing of the foot after the index operation, all of the patients elected to have their contralateral coalition resected in combination with adjunct procedures to repair the concomitant flatfoot deformity. Furthermore, the postoperative course for all of the feet proceeded without complications. At the most recent mean follow-up of 30 (range 16–54) months, all of the patients had maintained active lifestyles without pain, and all were able to participate in athletic activities whereas preoperatively they could not.

Discussion

Middle facet tarsal coalitions are often associated with rigid flatfeet in children and adolescents (17–20). In a literature review expanding 50 years, Stormount and Peterson (20) found that 314 tarsal coalitions had been reported and 37% involved the talocalcaneal complex, with the majority of those involving the middle facet. Such coalitions may occur bilaterally in as many as 50% of cases (2, 20–22). Tarsal coalitions frequently go unrecognized because the symptoms tend not to appear until mid to late adolescence (6, 19). As a result, patients may develop peroneal spastic flatfoot and secondary degenerative arthritis of the rearfoot complex (2, 4). When symptomatic arthritis is present, the mainstay for surgical treatment typically involves arthrodesis (2, 4), which is a joint destructive procedure that may result in prolonged disability (1, 23). However, when the coalition is diagnosed early without associated arthrosis, then the surgeon may choose to simply resect the coalition (4). Therefore, early diagnosis is important and evaluation of suspected cases with appropriate standard radiographs and CT can be helpful (1). More recently, poorer outcomes with failed resections and preoperative heel valgus have questioned the wisdom of performing isolated resection of the coalition. Appreciation of these poor outcomes may have led some surgeons to perform staged flatfoot reconstructions or concomitant procedural combinations aimed at resecting the coalition and also correcting the pes valgus deformity (5–6, 8, 11, 12).

In regard to placement of an interpositional material in the site of the resected coalition, numerous investigators have advocated isolated excision of the middle facet coalition with or without the addition of soft tissue interposition (5, 14, 24–29). Several researchers focused on comparing outcomes between interpositional materials in the resection site, rather than evaluating foot position before and after surgery. Potential substances used for interposition include adipose tissue, bone wax, flexor hallucis longus, and/or tensor fascia lata allograft (2, 6, 16, 27–29). It has been suggested that poorer long-term

Table 3 Comparison of preoperative and postoperative radiographic angles

Radiographic angle	Median (range) preoperative measurement, °	Median (range) postoperative measurement, °	*P* value (Wilcoxon signed ranks test)
Calcaneal inclination	7.5 (0, 11)	14.5 (10, 18)	.0273
Meary's	8 (2, 9)	3.5 (0, 6)	.0269
Talar-first metatarsal	9.5 (4, 18)	1 (0, 8)	.0277

outcomes or failures of simple resections were due to recurrence of the coalition, not the alignment of the foot (29). Because of this, most studies dealing with tarsal coalition surgery have focused on comparing simple resection with interposition of varying substances to prevent recurrence, rather than addressing the concomitant deformity of pes planus (Table 4). In 2 separate studies, Wilde et al (30) and Luhmann and Schoenecker (5) noted poorer outcomes with resection in the presence of severe heel valgus, defined as greater than 16° and greater than 21°, respectively, in the aforementioned investigations. To date, we are not aware of any study that has clearly linked the concomitant presence of postoperative pes planus with poor results following resection of the coalition. Additionally, while it is generally thought that pes planus may correct itself once motion is restored to the rearfoot, there are no studies or case reports illustrating this phenomenon. In those patients who develop arthrosis after simple resection, it is unclear if the arthritis is associated with the previous coalition or due to a persistent pes planus.

There are very few published reports on coalition resection with concomitant pes planovalgus correction. Yen et al (12) performed an isolated case of a middle facet coalition resection with an opening wedge calcaneal osteotomy of the tuber to correct rigid calcaneal valgus without internal fixation. In their case, tendo-Achilles lengthening was not performed despite the authors' acknowledgement of the triceps surae's contribution to calcaneal valgus. Collins (31) described isolated resection of the coalition though a medial incision, with insertion of a condylar implant into the plantar aspect of the talar surface of the resection site, in patients with ages ranging from 11 to 14 years. Collins reported positive results in 5 cases that were followed from 1 to 4 years, although he acknowledged that despite the procedural selection, there was foot pain associated with the concomitant pes planovalgus if foot orthotics were not worn postoperatively. Downey (8, 9) advocated resection through a medial incision coupled with arthroereisis through a lateral incision over the sinus tarsi. Similarly, Lepow and Richman (13) reported a case treated successfully with resection and arthroereisis. Cain and Hyman (7) described an isolated medial closing wedge calcaneal osteotomy for the treatment of 14 peroneal spastic flatfeet, some with tarsal coalition. They advocated use of the medial closing wedge calcaneal osteotomy in light of Dwyer's (10) supposition that pain in the presence of peroneal spastic flatfoot associated with congenital tarsal fusions is less significant in patients with less heel eversion.

Giannini and colleagues (11) reported on their experience with combined single-stage tarsal coalition resection and subtalar arthroereisis using a bioresorbable implant in 14 feet in patients with a median age of 14 (range 9–18) years and mean follow-up of 40 months. With the AOFAS ankle-hindfoot clinical rating system they observed 8 excellent results, 3 good results, and 3 fair results; and they observed no poor results or complications in their series. The authors noted that the 3 patients with the worst results were the oldest in the study, and suggested that arthroereisis completed before age 14 resulted in better outcomes because of the opportunity for bone remodeling in the younger subset. Furthermore, they concluded that hindfoot realignment with calcaneal osteotomy or subtalar joint fusion was preferred over arthroereisis in the skeletally mature patient whose coalition had already been resected, although Giannini and colleagues (11) did not report on their experience with rearfoot fusions or osteotomies in this demographic.

Westberry and colleagues (6) have performed a new method of coalition resection by completely excising the sustentaculum tali in 12 coalitions (10 patients). Eleven of the 12 resections in their study were rated as excellent or good results, with a mean postoperative AOFAS ankle-hindfoot score of 90 points. In their follow-up of 5.1 years, no coalition resection or progressive malalignment has been identified with this radical resection in their series of patients. One patient in their study had a poor result with persistent pain after the index procedure, and this was attributed to the nonsurgically treated pes planus rather than the sustentaculumectomy, and these symptoms resolved after subsequent surgical correction with a tendo-Achilles lengthening combined with lateral column lengthening 3 years after the initial procedure. In 4 of their patients, the sustentaculumectomy was concomitantly combined with additional procedures to correct foot alignment: 1 patient underwent a Dwyer closing wedge calcaneal osteotomy, another a gastrocnemius-soleus recession, and yet another patient had bilateral calcaneocuboid distraction arthrodeses. The latter patient had an excellent result on one foot and a poor result on the other. On review of the patient with the

Table 4 Clinical studies of middle facet talocalcaneal coalition resection

Investigator	Year	Sample size, patients (feet)	Age, y, at time of operation, mean (range)	Interposition material and concomitant procedures	Mo follow-up, mean (range)	Results (feet)
Olney and Asher[29]	1987	9 (10)	13.6 (10.5–22)	Fat	42 (25–91)	†E = 5, G = 3, F = 1, P = 1
Salomao et al[22]	1992	22 (32)	14 (10–23)	Bone wax and fat	25 (12–66)	78.1% feet completely painless, 21.8% feet achieved relief of pain. No objective pain scale used.
Kumar et al[27]	1992	16 (18)	14 (7–19)	Fat, tendon, or none	48 (24–96)	*E = 8, G = 8, F = 1, P=1
Kitaoka et al[16]	1997	11 (14)	17 yrs (13–32)	Fat, tendon, or none	72 (24–156)	*E = 5, G = 4, F = 3, P = 2
McCormack et al[28]	1997	8 (9)	13.6 (10.5–22)	Fat	138 (120–192)	‡E = 7, G = 0, F = 1, P = 1
Raikin et al[2]	1999	10 (14)	12 (9–16)	Split flexor hallucis longus tendon	51 (32–60)	*E =11, G = 1, F = 1, P=1
Westberry et al[6]	2003	10 (12)	12.7 (9.0–17.9)	Bone wax and complete sustentaculum tali excision	61.2 (18–104)	*E = 8, G = 3, F = 0, P = 1

Abbreviations: E, excellent; G, good; F, fair; P, poor.
*Denotes that the study used AOFAS ankle-hindfoot clinical rating system.
†Denotes that the study used the Chambers Functional Test.
‡Denotes that the study used the Painful Foot Center questionnaire.

poor result on one side, the investigators concluded that it was not due to improper foot alignment, coalition recurrence, or poor union of the calcaneocuboid arthrodesis site. Instead, they attributed the poor result to severely restricted hindfoot and ankle motion.

Secondary arthrosis may develop in the rearfoot complex as a result of tarsal coalition and, when present, simple resection alone may prove to be an inadequate surgical solution. In some cases, isolated arthrosis of the subtalar joint may occur and this may best be determined with a CT scan. Scranton (32) suggests that when greater than 50% of the subtalar joint is involved, that arthrodesis be performed. Luhmann and Schoenecker (5) demonstrated that a statistically significant poorer outcome was associated with a talocalcaneal coalition involving greater than 50% of the surface area of the posterior facet, as identified with a CT scan. Although those authors pointed out that 8 of 25 feet with a talocalcaneal coalition involving more than 50% of the surface area of the posterior facet had good or excellent results, they also stated ". . .talocalcaneal coalition size does not absolutely predict post-resection outcome" (5). In regard to narrowing of the posterior facet as viewed on CT scan, Wilde et al (30) reported a less optimal result in those feet that displayed narrowing of the posterior facet, whereas Luhmann and Schoenecker (5) did not find that a narrowed posterior facet had a significant negative effect on short-term outcome. Still further, Comfort and Johnson (25) found that good or excellent clinical results were achieved in 77% of 17 coalition resections that involved less than one third of the entire subtalar joint surface, as measured on a coronal CT view. McCormack et al (28) performed coalition resection with fat interposition in the presence of talar beaking. In the absence of talonavicular joint arthritis, the senior author (N.M.B.) believes that resection, as compared to isolated realignment subtalar joint arthrodesis, should be attempted in the absence of significant subtalar joint spurring and subchondral cysts with less than 50% posterior facet involvement as evidenced on the CT scan. Kumar et al (27) advocated resection of all coalitions, regardless of the extent of middle facet involvement, if a 6-week period of conservative immobilization failed to ameliorate symptoms. Based on their results demonstrating poor outcomes in the presence of advanced heel valgus, Luhmann and Schoenecker (5), recommended that a secondary calcaneal procedure be considered in feet with more than 21° of heel valgus if foot orthotic therapy failed to ameliorate symptoms. Additionally, they contended that hindfoot arthrodesis should be performed as a salvage procedure only (5, 18). Last, Wilde et al (30) documented the association of hindfoot valgus greater than 16° with poor outcomes.

Isolated subtalar fusion or triple arthrodesis remains the definitive treatment in patients with advanced degeneration, despite the fact that this form of intervention is not without a range of short and long-term sequelae (12, 18, 23, 26, 33, 34). Because triple arthrodesis is thought to cause an increased incidence of ankle and midfoot arthrosis, one should attempt to delay joint destructive interventions, especially in young patients (1, 35–39). Although rearfoot arthrodesis procedures should be avoided until skeletal maturity, sur-

Table 5 Blitz and Kernbach proposed classification and surgical treatment algorithms for symptomatic middle facet talocalcaneal coalitions (TCC)

Type of coalition	Associated pathology	Intervention
I	TCC + pes planus without rearfoot arthrosis	Resection of the coalition
II	TCC + mild pes planus without rearfoot arthrosis	Resection ± flatfoot* reconstruction
	TCC + moderate pes planus without rearfoot arthrosis	Resection ± flatfoot* reconstruction
	TCC + severe pes planus without rearfoot arthrosis	Resection ± flatfoot* reconstruction or appropriate rearfoot arthrodesis
III	TCC + pes planus with symptomatic subtalar arthrosis	Subtalar fusion ± flatfoot* reconstruction or triple arthrodesis
	TCC + pes planus with symptomatic subtalar and talonavicular arthrosis	Subtalar and talonavicular fusion ± flatfoot[1] reconstruction or triple arthrodesis
	TCC + pes planus with symptomatic subtalar, talonavicular and calcaneocuboid arthrosis	Triple arthrodesis

*Flatfoot reconstruction may involve one or a combination of the following depending on the plane of deformity and skeletal maturity: subtalar arthroereisis, medializing calcaneal osteotomy, Evans osteotomy or distraction calcaneocuboid arthrodesis, gastrocnemius recession, tendo-Achilles lengthening, and/or medial column procedure/fusion.

geons may perform rearfoot arthrodeses in the absence of arthrosis in cases of severe pes planovalgus (3). To date, we are not aware of any reports that compare the outcomes for coalition resection versus triple arthrodesis, but it is generally believed that joint preservation is critical in this young patient population (5, 23).

Correction of the associated pes planus is classically considered as a secondary procedure only after isolated resection of a tarsal coalition has progressed to failure (5, 6). More recently, studies have suggested that poorer results with coalition resection alone may be due to the presence of pes planus, and that this has led some surgeons to perform concomitant single-stage soft tissue and osseous procedures. The results of the study of Giannini and colleagues (11), wherein coalition resection was combined with resorbable subtalar arthroereisis, are encouraging because the interventions directly addressed the concomitant pes planus deformity. However, their study was not of suitable duration to be able to ascertain whether or not the pes planus correction will hold up after the arthroereisis implant has been resorbed. Westberry et al (6) completely excised the sustentaculum tali in 12 coalitions (10 patients), and one of these patients underwent concomitant bilateral calcaneocuboid distraction arthrodesis for the correction of pes planus. Subsequent procedures were required in one of their patients, who complained of persistent pain that was determined to be related to the persistence of significant residual pes planovalgus deformity. In that particular patient, lateral column lengthening as well as tendo-Achilles lengthening was undertaken 3 years after the initial surgery, with resolution of symptoms noted at the most recent follow-up 2 years after the second surgery. The 6 feet that we present in this retrospective review, all of which underwent a single-stage coalition resection combined with flatfoot reconstruction, demonstrated excellent clinical results as determined by the mean AOFAS ankle-hindfoot score of 94.33 ± 2.81 points, as well as the statistically significantly improved radiographic angles. Moreover, we performed this reconstruction in 3 patients with bilateral coalitions who had the first operation performed at least 6 months before the contralateral extremity. The fact that all 3 of the patients elected to proceed with surgical repair of their contralateral extremity further suggested that the degree of improvement warranted, in the mind of the patients, repair of the contralateral foot and ankle deformities. It is our hope that the single-stage coalition resection coupled with flatfoot reconstruction will maintain the pes planus correction (partial or complete), and prevent the development of tarsal arthrosis and obviate the need for rearfoot joint fusion(s) and the morbidities associated with such interventions.

Based on Downey's surgical classification of tarsal coalitions (40), and our limited experience with the 6 feet in 3 patients described in this article, we present a revised classification scheme and an algorithm for the surgical treatment of symptomatic middle facet talocalcaneal coalition that incorporates concomitant pes planus correction (Table 5). While this classification scheme may be somewhat premature based on this retrospective review of a small series of cases, the concepts are based on established surgical principles for both symptomatic middle facet tarsal coalition and flatfoot reconstruction. The treatment algorithms that we propose, moreover, are also based on our limited experience, and are presented with the understanding that the value of these treatment recommendations, as well as the classification system, require the evaluation of a larger cohort of patients in order to reliably assess their usefulness. We recommend that the method of osseous flatfoot reconstruction be based on the clinical exam, skeletal maturity, and the degree and planal dominance of the deformity (23). The surgeon should consider the need for rearfoot arthrodesis if resection of the coalition should fail, or when performing a coalition resection in conjunction with osseous

flatfoot reconstruction. We are not suggesting that all symptomatic middle facet coalitions associated with pes planus be treated with these algorithms; however, we do encourage surgeons to consider the potential usefulness of these combinations of interventions. Simple resection without concomitant pes planus correction currently remains the traditional accepted method of treatment. Traditional approaches notwithstanding, we present these algorithms as a potential guideline when the surgeon believes that the pes planus deformity contributes to the patient's symptoms and, in an effort to alleviate the symptoms, surgical intervention is being considered. Moreover, it is our hope that the proposed classification and algorithm scheme (Table 5) be used to compare and contrast future studies, and also contribute to the attainment of improved outcomes, since the indications for resection versus arthrodesis have yet to be made clear (6).

Like most retrospective investigations, the results of the current study were subject to the influence of a number of methodological shortcomings. One potential limitation of this study is that there may have been a quantitative error in the measurement of the radiographic measurements used. It has been previously demonstrated that variation exists in regard to radiographic measurements secondary to interobserver and intraobserver reliability (41–44). Additionally, Thomas et al (41) noted in their radiographic review of 200 feet, with over 6000 computer-aided measurements, that the talar bisection was particularly difficult to consistently identify in both the anterior-posterior and lateral views. In our investigation, all of the plain film radiographic measurements were obtained by the same investigator (K.J.K.) in an effort to limit interobserver variability, although intraobserver error may have influenced the measurements. Because we were able to show a statistically significant improvement in all of the radiographic variables that we measured, it is most likely that the combination of surgical procedures was the cause of the improvement in these continuous numeric variables.

Another limitation of this study was the small sample of feet involved and the retrospective nature of the inquiry. Because we only reviewed 6 feet in 3 patients, we are not able to say with certainty that the concomitant flatfoot reconstructive procedures were directly responsible for the clinical improvement that we observed. Moreover, we did not measure pre- and postoperative subtalar joint range of motion, which may have been a useful independent variable in regards to assessment of the effect resection of the talocalcaneal joint coalition. Furthermore, we did not have preoperative AOFAS scores for comparison with the postoperative scores that we obtained, and we used the AOFAS score in patients that were all younger than 18. Nonetheless, the postoperative AOFAS scores that we obtained were considerably high (94.33 ± 2.81, out of 100 possible points), and suggested that the patients were symptomatically and functionally improved following the surgical intervention.

It may be difficult or impossible to obtain a perfect radiographic alignment in certain severe cases of pes planus, despite the method of surgical correction. In the patients described in this series, postoperative alignment of the patients' feet was not absolutely perfect from a clinical or radiographic standpoint, despite that the alignment was much improved after the reconstructive surgery. Our intention was to improve the overall foot alignment by preserving the rearfoot complex while avoiding rearfoot fusions, especially in the skeletally immature patients in our series. As such, in the 4 skeletally immature feet with transverse plane deformities, we elected to perform the Evans calcaneal osteotomy rather than calcaneocuboid distraction fusions. Although we may have achieved better transverse plane correction in these 4 feet with a calcaneocuboid distraction fusion, we felt the patients were young enough to potentially adapt and that the foot alignment would continue to improve over time following the operation. The variations in surgical management between patients may also be interpreted as a possible limitation in this retrospective review, where we used different materials for interposition following resection of the coalition, as well as different combinations of adjunct procedures. However, the authors wish to emphasize that the precise method of flatfoot reconstruction may be surgeon dependent and the authors suggest that with improved anatomic alignment in a growing patient, function may be improved over the course of musculoskeletal development and maturity. Of course, such speculation can only be thoroughly evaluated by means of properly designed cohort studies of sufficient sample size to enable the statistical comparison of a number of independent variables with an outcome variable that defines a satisfied patient over an extended period of time.

The results of this small retrospective study bring forward many questions regarding middle facet talocalcaneal coalitions that are associated with pes planus. How much of the preoperative pain is associated with the coalition itself versus the concomitant pes planus? Should simple resection be performed in all cases regardless of foot position, despite some evidence that pes planus has been associated with poor outcomes? In those patients who develop rearfoot arthrosis after simple coalition resection, is the arthritis associated with the normal progression or sequelae after resection of the coalition resection; or, is recurrence of the coalition due to persistent pes planus? Under what clinical or radiographic criteria should fusion(s) be performed? What specific role does CT play in determining whether or not fusion(s) should be performed? Does the type of coalition play a role in the development of subtalar and/or adjacent joint arthrosis? Should concomitant pes planus correction be reserved for cases of failed isolated resection? Is there a definite role for single-stage middle facet coalition resection with concomitant flat foot reconstruction?

Long-term studies regarding the outcomes of tarsal coalition surgery are needed, as are studies to determine the predictive value of a useful classification scheme that aids in the determination of the best treatment for symptomatic tarsal coalition.

In conclusion, concomitant treatment of pes planus associated with middle facet talocalcaneal coalition resection is not a totally new concept. There have been sporadic case reports that describe the surgical treatment of the pes planus deformity along with resection of the coalition, however the concept does not seem to have become mainstream practice. Recent evidence suggests that the concomitant presence of pes planus may play more of a role in the development and persistence of pain than what the literature has historically considered. We present our experience in a small series of patients (6 feet in 3 patients) having undergone middle facet coalition resection combined with flatfoot corrections that addressed all of the elements of the foot deformity. This combined technique resulted in statistically significant improvements in the radiographic measurements, and a mean postoperative AOFAS ankle-hindfoot of 94.33 ± 2.81 points. These results suggest that this single-stage approach may play a greater role in the surgical treatment of middle facet tarsal coalitions and spark future investigation, and the results of this preliminary investigation can be used in the development of future studies into the nature and outcomes of this condition and its treatment.

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