Surgical Treatment for Painful Pediatric Pes Planovalgus: How Does Subtalar Extra-articular Screw Arthroereisis Compare to the Standard Technique of Modified Evans Reconstruction?

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Background: A subset of patients with flexible pediatric pes planovalgus (PPV) will have recalcitrant symptoms and functional impairment despite maximizing nonoperative methods and seeking surgical care. The primary aim of this study was to compare the clinical course and radiographic improvement including final alignment for patients who underwent the minimally invasive corrective subtalar extra-articular screw arthroereisis (SESA) technique compared with the traditional modified Evans reconstruction (MER) technique for flexible PPV correction.

Methods: Forty-five feet in 31 PPV patients aged 10 to 19 years treated at a single institution with (1) SESA +/− Vulpius or accessory navicular or tarsal coalition excision (22 feet) or (2) MER +/− Vulpius (23 feet) from 2010 to 2022 were identified. Patients with no weight-bearing postoperative x-rays were excluded. Comprehensive preoperative and postoperative radiographic measurements were obtained from standing radiographs. Radiographic outcomes were evaluated across treatment groups using noninferiority analysis. Comparisons in clinical characteristics were conducted using mixed-effects regression modeling to account for the correlation between bilateral measurements within the same patient.

Results: Surgery was performed at an average age of 13.7 years (SD, 1.9); the cohort was 53% male. There were no differences in age, BMI, or laterality between the SESA and MER cohorts. The SESA cohort had a significantly shorter operative time compared with MER (51 vs. 167 min; $P<0.001$). One patient in the MER cohort required a return to the operating room for hardware removal in the setting of pseudoarthrosis, and another for a buried pin. Time to weightbearing in the SESA cohort was a median 3 weeks earlier than the MER cohort ($P=0.004$). The SESA procedure was found to be noninferior to MER with respect to postoperative radiographic alignment as well as in the improvement in alignment from preoperative to postoperative measurement (all $P<0.05$).

Conclusions: For painful pediatric pes planovalgus (PPV), subtalar extra-articular screw arthroereisis (SESA) offers a less invasive approach with noninferior outcomes compared with modified Evans reconstruction (MER). Our study found similar radiographic improvements and deformity correction in adolescents treated with SESA versus MER, along with shorter procedures and earlier weightbearing. No major complications were observed. Long-term follow-up and patient-reported outcome studies are needed, especially postscrew removal.

Level of Evidence: Therapeutic case-control study, level III.

Key Words: pes planovalgus, pes planus, modified Evans reconstruction, subtalar extra-articular screw arthroereisis, calcaneo-stop

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Flexible flat foot, or pes planuvalgus (PPV), is a common finding in pediatric patients. A recent Cochrane review estimated that about 44% of children younger than 10 years old and about 15% of older children have flat feet.[1] Most flat foot deformities self-correct with increased age and are within normal range by adult age. Staheli described in 1999 the difference between physiological and pathologic flat foot. While the physiological flat foot improves with time, pathologic flat foot tends to present with stiffness and cause functional disability, requiring treatment.[2] In symptomatic pediatric patients, idiopathic flexible flat foot typically presents with a valgus hindfoot, midfoot abduction with forefoot supination, and collapse of the medial longitudinal arch.[3]

Nonoperative treatment of symptomatic patients includes orthoses such as the University of California Biomechanics Laboratory (UCBL) along with physical therapy, which has some reported benefit in a select subset of patients, although compliance remains an issue.[4] Surgical management is indicated in patients who, despite nonoperative measures, remain with symptomatic flexible flat foot. Traditionally, the widely accepted surgical

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treatment in pediatric patients involve a complex procedure with various modifications including lateral column lengthening,[5] in addition to medial soft tissue re-alignment as described by Mosca,[6] and possible medial cuneiform plantarflexion osteotomy[7]; this is often collectively known as a modified Evan reconstruction (MER) which has been reported to have good medium-term outcomes.[8] In addition to operative complexity, the postoperative course for young patients involves non-weightbearing, often for several months, and delayed return to sports with variable rates of return to preoperative levels of physical activity.[9,10] Other described techniques include intra-articular subtalar arthroereisis, which involves the insertion of an intra-articular peg to affect the mechanics of the subtalar joint. While some studies showed promising results for this traditional intra-articular subtalar arthroerisis procedure, concerns have arisen; not all problems are reported in the literature, making the reporting of the exact prevalence of synovitis and cartilage damage difficult.[11,12] Sinus tarsal pain after this procedure can be common, resolving after removal of the implant.[11,12]

A minimally invasive subtalar extra-articular screw arthroereisis (SESA) technique has been described for the treatment of children who are 10 years old or older with symptomatic flexible flat foot that have failed non-operative treatment. The SESA procedure, also known as the "calcaneo-stop" procedure, involves inserting a single screw into the calcaneus with promising results including early return to sports within 3 months for young athletes.[13,14] This has been reported to have good medium-term to long-term outcomes in patients in Europe.[14,15] The primary aim of this study was to compare the clinical course and radiographic improvement, including final alignment, for patients who underwent the minimally invasive corrective SESA technique compared with the traditional MER technique for PPV correction. We hypothesized that the SESA technique would yield noninferior radiographic improvement as compared with the MER technique.

METHODS

With institutional review board approval, patients with PPV treated at a single institution with either SESA with or without concomitant Vulpius or accessory navicular excision or MER with or without concomitant Vulpius from 2010 to 2022 were retrospectively identified. Surgeon preference dictated the surgical technique (MER or SESA) at our institution, where the MER procedure was performed by several different surgeons, but the SESA was performed by a single surgeon (senior author on this paper) after being trained in this technique; all surgeons were board-certified pediatric orthopaedic surgeons. Patients who underwent a MER had surgery as described by Mosca,[6] typically including a calcaneal lengthening osteotomy along with a medial cuneiform osteotomy, Achilles recession, and medial reefing of the talonavicular capsule and posterior tibialis tendon shortening. Patients who underwent a SESA had surgery as described by De Pellegrin et al,[13] possibly with an Achilles recession or other procedures as indicated. The postoperative course was determined by the individual treating surgeon. Typically, after MER patients were non-weightbearing for 4 to 8 weeks (surgeon preference), while in the SESA patients who had just a SESA were able to weight bear within a week without supportive devices, those who had other procedures had a cast and weight-bearing status depending on the exact procedure. Inclusion criteria encompassed patients between the ages of 10 and 18 years old at the time of index surgery at our institution. Exclusion criteria were patients with no weightbearing preoperative or postoperative x-ray, patients with neuromuscular flat foot, and trisomy 21 patients.

Comprehensive preoperative and postoperative radiographic measurements were obtained from standing anterior-posterior (AP) and lateral radiographs for the 2 groups. Images were reviewed using Synapse PACS, and measurements were completed on the software by 2 experienced pediatric orthopaedic fellows or board-certified surgeons. On the AP radiographs, we measured: (1) the talo-first metatarsal angle, defined as the angle between a line along the longitudinal axis of the talus and a second line along the longitudinal axis of the first metatarsal, (2) the talonavicular coverage angle, calculated by drawing a line from the medial to lateral margins of the articular surface of the navicular comparing the perpendicular to an axial line down the talus, (3) the talo-calcaneal angle, calculated from the angle between a line along the longitudinal axis of the talus and another line along the longitudinal axis of the calcaneus, and (4)the talo-fifth metatarsal angle was defined as the angle between a line along the longitudinal axis of the talus and another line along the longitudinal axis of the fifth metatarsal. These were described and validated by Davids et al[16] and Moraleda and Mubarak.[17]

On lateral weight-bearing foot radiographs we measured: (1) the lateral talo-first metatarsal angle (Meary's angle), defined as an angle between the long axis of the talus and a line through the axis of the first metatarsal, (2) the lateral calcaneal pitch, was measured as an angle between the plantar aspect of the calcaneus and another line through the line along the plantar aspect of the soft tissue shadow of the hindfoot, (3) the lateral tibia-calcaneal angle is measured as an angle through the tibial shaft the plantar aspect of the calcaneus, (4) the talo-calcaneal angle is the measured the plantar aspect of the calcaneus and a line through the axis of the talus, (5) the calcaneal-fifth metatarsal angle was defined as a line through the plantar aspect of the calcaneus and the long axis of the fifth metatarsal and (6) lastly, the naviculo-cuboid overlap, measured as the ratio between the distance from the superior margin of the cuboid and the inferior margins of the navicular and the distance from the superior and inferior margins of the cuboid. These have also been described and validated by Davids et al[16] and Moraleda and Mubarak.[17]

Further, we collected demographic and clinical data for the 2 cohorts, including age in years at the time of surgery, sex, body mass index (BMI) in kg/m2, operative side laterality, operative time in minutes defined as surgeon time in the intra-operative record (time from incision to wound closure), and complications. Time to weightbearing after immobilization. Complications were defined as either major (defined as unplanned return to the operating room) or minor.

Comparisons across treatment groups were conducted using mixed-effects regression modeling to account for the correlation between bilateral measurements within the same patient. Noninferiority analysis was conducted on postoperative radiographic alignment and for the change in radiographic measures from preoperative to postoperative across treatment groups. Linear mixed modeling was implemented, and noninferiority was assessed using a 1-sided test of the regression effects for a minimal noninferiority margin of 8 degrees. We chose a NIM of 10 degrees a priori based on what would be a clinically relevant amount of acceptable difference across treatment groups. The results reflect 8 degrees, as we were powered to tighten that margin when conducting the final analysis. Reported means and SDs are model-adjusted estimates using the corresponding mixed-effects regression model. P-values <0.05 were considered significant.

Power analysis determined that samples of 22 and 23 feet in each treatment group provided 80% power to test for noninferiority of the SESA group compared with MER up to a noninferiority margin as small as 8 degrees for radiographic alignment measurements. This was determined using 1000 bootstrap resampled estimates of the linear mixed-effects models, and conducting a 1-sided t test for the treatment effect. Power was calculated as the proportion of bootstrap samples in which noninferiority was supported ($P<0.05$). For comparisons in surgical characteristics across groups, the achieved sample sizes provided 80% power to test for effect sizes as small as 0.85 with alpha set to 5%.

TABLE 1. Demographic and Preoperative Characteristics by Procedure Group

Characteristic	SESA (N = 22) n (%)	MER (N = 23) n (%)	P*
Age [y; mean (SD)]	13.9 (2.1)	13.5 (1.6)	0.40
Sex (% male)	9 (41)	15 (65)	0.18
BMI percentile [median (IQR)]	93 (88-97)	90 (79–95)	0.43
Surgical time [min; mean (SD)]	51 (35.6)	167 (62.8)	< 0.001
Tourniquet time [min; mean (SD)]	36 (16.3)	97 (28.3)	< 0.001
Casting (% yes)	12 (55)	23 (100)	< 0.001
Days spent in the cast [wk; mean (SD)]	3.4 (2.4)	7.2 (2.6)	< 0.001
Days to weightbearing [wk; median (IQR)]	4 (1-4)	7 (6-9)	0.004
Preoperative radiographs	Mean (SD)	Mean (SD)	
Standing AP			
Talo-first metatarsal angle	24.1 (10.2)	21.7 (9.2)	0.43
Talonavicular coverage angle	37.5 (16.4)	32.3 (12.2)	0.23
Talo-calcaneal angle	19.6 (7.0)	23.1 (8.9)	0.21
Talo-fifth metatarsal angle	42.4 (8.8)	39.5 (9.7)	0.35
Standing lateral			
Meary's angle, talo-first metatarsal angle	17.8 (9.4)	25.4 (8.6)	0.02
Talo-calcaneal angle	49.7 (8.7)	52.0 (7.5)	0.35
Tibio-calcaneal angle	74.8 (5.8)	78.5 (6.9)	0.09
Calcaneal pitch angle	15.2 (6.1)	11.4 (4.1)	0.07
Talohorizontal angle	38.5 (7.6)	42.2 (8.5)	0.20
Fifth metatarsal angle	24.4 (8.7)	22.0 (7.2)	0.62
Additive alignment			
Hindfoot alignment	123.1 (15.2)	128.8 (16.0)	0.26
Midfoot alignment	107.3 (34.6)	111.3 (19.6)	0.81
Forefoot relative to hindfoot	108.7 (22.7)	108.6 (20.8)	0.96
Talocalneal index	69.4 (8.8)	75.2 (11.0)	0.06

*P-values are based on mixed-effects regression models to account for the correlation between bilateral measurements within the same patient

IQR indicates interquartile range (25th percentile to 75th percentile); MER, modified Evans reconstruction; SESA, subtalar extra-articular screw arthroereisis.

RESULTS

Forty-five feet in 31 patients with surgically treated PPV were evaluated at preoperative and postoperative time points between January 2010 and December 2022. Index surgeries occurred at an average age of 13.7 years (SD, 1.9), and the cohort was 53% male. Average follow-up was 26 months (range, 2 to 80 mo). Twenty-two feet (22/45, 49%) in 14 patients underwent SESA, while 23 feet (23/45, 51%) in 17 patients underwent MER (Table 1). In our institution, we have several surgeons who perform the MER while only 1 surgeon is trained in the SESA (senior author); since trained in the technique, this author has used SESA over MER exclusively for surgically treated flexible PPV. Differences were detected in preoperative radiographic assessment for Meary's angle (SESA, 17.8 degrees vs. MER, 25.4 degrees; $P=0.02$).

In the SESA group, only feet with concomitant Vulpius (n = 10, 45%), accessory navicular excision (n = 1) or calcaneonavicular tarsal coalition excision (n = 2, 10%) were immobilized in cast or splint; whereas all of the MER feet were cast postoperatively. The mean time spent in the cast for the SESA group was 3 weeks (SD, 2.4) compared with 7 weeks (SD, 2.6) for the MER group ($P<0.001$).

Noninferiority analysis found that the SESA technique was noninferior to MER for all postoperative radiographic measurements (all $P<0.05$) except for the standing talo-fifth metatarsal angle ($P=0.27$) (Table 2). Some measurements, including Meary's angle, lateral tibio-calcaneal angle, talohorizontal angle, and additive hindfoot alignment, were found to have superior postoperative alignment for SESA compared with MER (Table 2). When assessing change in radiographic measures, noninferiority was achieved for all radiographic assessments (all $P<0.05$; Table 3).

Comparing clinical course, there were no differences detected with respect to age at the time of index surgery ($P=0.40$) or BMI ($P=0.43$) between the SESA and MER cohorts (Table 1). Thirteen (59%) feet in the SESA group

TABLE 2. Postoperative Radiographic Measures by Treatment Group

Postoperative	SESA (N = 22) Mean (SD)	MER (N = 23) Mean (SD)	(95% NI CI)	NIM	*P**
Standing					
Meary's angle	5.6 (5.3)	13.4 (9.7)	(−11.9 to −2.8)	8	< 0.001
Talo-first metatarsal angle	9.8 (8.4)	9.8 (8.0)	(−3.7 to 5.7)	8	0.007
Talonavicular coverage angle	14.3 (9.6)	13.8 (11.4)	(−4.4 to 7.7)	8	0.04
Talo-calcaneal angle	17.2 (6.2)	19.8 (6.5)	(−5.8 to 1)	8	< 0.001
Talo-fifth metatarsal angle	33.2 (9.8)	28.0 (8.6)	(0.8 to 11.3)	8	0.27
Lateral					
Talo-calcaneal angle	72.6 (6.5)	73.6 (6.8)	(−4.3 to 3.2)	−8	0.001
Tibio-calcaneal angle	43.3 (6.2)	48.3 (7.6)	(−10.1 to −1.9)	8	< 0.001
Calcaneal pitch angle	17.4 (7.3)	17.0 (4.7)	(−4.1 to 2.7)	−8	< 0.001
Talohorizontal angle	28.7 (4.9)	34.0 (6.7)	(−9 to −2.2)	8	< 0.001
Fifth metatarsal angle	26.4 (9.2)	25.4 (7.1)	(−4.8 to 4.4)	−8	0.003
Additive alignment					
Hindfoot alignment	135.9 (7.5)	144.4 (12.2)	(−14 to −3.3)	−15	0.03
Midfoot alignment	56.9 (26.3)	68.1 (29.5)	(−25.1 to 8.8)	20	0.003
Forefoot relative to hindfoot	75.0 (21.6)	76.7 (18.7)	(−11.9 to 11.6)	15	0.02
Talocalneal index	89.8 (8.7)	93.4 (10.1)	(−8.2 to 1.8)	−10	0.01

All summary statistics are model-adjusted to account for bilateral measurements within the same patients.

**P*-values are based on 1-sided tests of effects using linear mixed-effects modeling against the given noninferiority margin value. Values < 0.05 indicate that SESA is noninferior to MER with respect to the measurement and the noninferiority margin provided.

CI indicates confidence interval; MER, modified Evans reconstruction; NI, noninferiority; NIM, noninferiority margin; SESA, subtalar extra-articular screw arthroereisis.

were in females and 15 (65%) feet in the MER group were in males. In terms of surgical time, the SESA cohort had a shorter mean time of 51 minutes (SD, 36) versus 167 minutes (SD, 63) for the MER cohort ($P < 0.001$). Figure 1 illustrates the mean surgical time for the SESA procedure (with and without concomitant procedures) compared with MER.

In the current study, the time to weightbearing out of cast in the SESA cohort was 4 weeks earlier compared with the MER cohort ($P < 0.001$). Feet that underwent the SESA procedure without application of a cast were weightbearing at an average of 10 days postoperatively; patients who had only a Vulpius along with their SESA were allowed to weight bear as tolerated in a cast from postoperative day 2 onwards. Overall, patients in the SESA group were cleared for weightbearing outside of their cast at a mean of 3 weeks (IQR, 1 to 4) compared with 7 weeks (IQR, 5 to 9) in the MER group ($P = 0.004$).

Postoperative follow-up was a median of 17 months for the SESA group and 21 months for the MER group. There were no major complications in the SESA group requiring an unplanned return to the operating room. Two patients in the MER group had a major complication necessitating an unplanned return to the operating room: 1 patient for hardware removal in the setting of pseudoarthrosis and another for a buried pin. SESA patients are routinely recommended a scheduled return to the operating room for hardware removal around 3 years after implant insertion. In our study so far, 6 extremities (27%) have had hardware removal at an average of 3.3 years.

DISCUSSION

We compared the clinical course and radiographic outcomes of pediatric patients treated for painful pes planovalgus using 2 different surgeries: the standard foot reconstruction using the modified Evans technique (MER) and the minimally invasive subtalar extra-articular screw arthroereisis (SESA). We have chosen not to pursue the traditional intra-articular arthroereisis given concerns within the pediatric orthopaedic community (James Kasser, MD, personal oral communication); in addition, other orthopaedic surgeons have moved away from this procedure, although comprehensive complications are not reported in the literature.[11,12] We found that patients who underwent the SESA procedure had a significantly shorter operative time and were able to return to weight-bearing activities significantly earlier than patients who underwent the MER. This is not surprising given its minimally invasive approach. Also, only half of the patients in our cohort who underwent SESA needed to be cast. Further, in the current cohort, there were no major complications in the SESA group necessitating an unplanned return to the operating room, while there were 2 major complications in the MER cohort. In terms of radiographic measurements, we found that patients treated with the SESA procedure had noninferior improvements in radiographic measurements to correct their PPV deformity compared with patients treated with the MER, and some radiographic measurements showed improved correction relative to MER.

At present, there is a paucity of information on outcomes related to SESA, particularly in the North American literature. The senior author previously published their initial early North American experience with high patient satisfaction surveys, when they evaluated 33 feet with an average follow-up of 12 months (range, 8 to 21 mo), but longer-term outcomes and comparison to the current standard of treatment were needed.[18] Our findings

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TABLE 3. Change in Radiographic Measurements From Preoperative and Postoperative by Treatment Group

Postoperative	SESA (N = 22) Mean (SD)	MER (N = 23) Mean (SD)	(95% NI CI)	NIM	P*
Standing					
Meary's angle on lateral x-ray	−12.1 (9.0)	−12.0 (9.0)	(−5.1 to 5.2)	8	0.005
Talofirst metatarsal angle	−14.3 (7.8)	−12.0 (9.9)	(−6.7 to 3.3)	8	0.001
Talonavicular coverage angle	−23.2 (14.5)	−18.5 (14.6)	(−12.4 to 3.4)	8	0.005
Talo-calcaneal angle	−2.5 (7.9)	−3.3 (10.1)	(−3.9 to 5.5)	8	0.006
Talo-fifth metatarsal angle	−9.2 (7.9)	−11.4 (10.7)	(−2 to 7.3)	8	0.03
Lateral					
Talo-calcaneal angle	22.9 (10.9)	21.5 (10.1)	(−4.8 to 9.1)	−8	0.008
Tibio-calcaneal angle	−31.5 (8.5)	−30.2 (9.0)	(−7.8 to 3.3)	8	0.001
Calcaneal pitch angle	2.2 (3.6)	5.6 (4.1)	(−5.8 to −1.5)	−8	< 0.001
Talohorizontal angle	−9.9 (9.0)	−8.3 (8.7)	(−7.9 to 2.8)	8	0.001
Fifth metatarsal angle	2.0 (6.2)	3.4 (5.7)	(−4.5 to 1.7)	−8	< 0.001
Additive alignment					
Hindfoot alignment	12.8 (14.1)	15.6 (18.0)	(−10.7 to 4.7)	−15	0.005
Midfoot alignment	−50.5 (32.7)	−43.2 (35.2)	(−22.8 to 17)	20	0.03
Forefoot relative to hindfoot	−33.6 (18.6)	−32.0 (23.3)	(−11.9 to 10.8)	15	0.01
Talocalneal index	20.5 (9.6)	18.2 (14.3)	(−3.5 to 8)	−10	< 0.001

All summary statistics are model-adjusted to account for bilateral measurements within the same patients

**P*-values are based on 1-sided tests of effects using linear mixed-effects modeling against the given noninferiority margin value. Values < 0.05 indicate that SESA is noninferior to Evans with respect to the measurement and the noninferiority margin provided.

CI indicates confidence interval; MER, modified Evans reconstruction; NI, noninferiority; NIM, noninferiority margin; SESA, subtalar extra-articular screw arthroereisis.

in this study, unique in comparing outcomes of SESA and MER procedures conducted at a single institution, suggest that for adolescent patients with symptomatic PPV, the SESA procedure offers patients an alternative to traditional osteotomies that achieve corrections similar to those obtained with traditional osteotomies, but with lower complication rate, shorter operative times, and faster return to activities. These results can help guide clinicians when assessing different surgical treatment options for pediatric pes planovalgus.

Most of the previous literature on SESA has come from the European literature, where the procedure was initially developed.[19] In 2014, De Pellegrin et al[13] reported on their experience with the SESA technique in treating flat foot in children between the years of 1990 and 2012 at

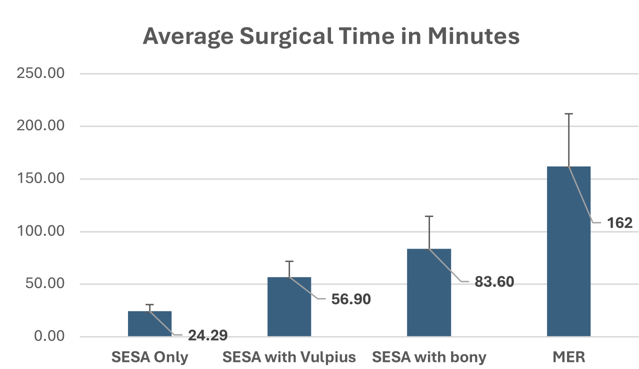

FIGURE 1. Comparison of average surgical time in minutes between subtalar extra-articular screw arthroereisis (SESA) only, SESA plus Vulpius type Achilles lengthening, SESA combined with other bony procedures and modified Evans reconstruction (MER). full color online

an average follow-up of 4.5 years (range, 3.1 to 13.2 y). Like our study, the authors reported satisfactory radiographic improvements in correction of flat feet with a very low complication rate. Also, the authors continued to follow a subset of patients after the scheduled removal of hardware (which occurred at 2.9 y postinsertion); even after removal of the SESA screw they found ongoing persistence of the radiographic correction.[13] Further, Pavone et al,[14] and more recently Elmarghany et al[20] reported on their patients treated with the SESA technique. Pavone et al[14] had a mean follow-up of 58 months and Elmarrghany et al[20] 29 months. These authors also found improved alignment radiographically, improved function, and return to activities based on validated patient-reported outcomes.[20] Pavone et al[14] reported that adolescent patients who underwent the SESA procedure were able to return to sports within 3 months. In a recent meta-analysis of 2394 feet, Galan-Olleros et al[21] evaluated the literature on the efficacy of the SESA procedure and found significant improvements in radiologic measurements, postoperative pain, and an increase in patient-reported outcomes along with a low complication rate. While we did not collect patient-reported outcomes, our results concur with the findings in terms of improved alignment, early return to activities, and low complications.

Costa et al[15] reported on the long-term outcomes of the SESA (also known as calcaneo-stop) procedure at a mean of 12 years after the procedure. While some patients had heel valgus and flat foot seen clinically, the FAOS questionnaire showed mean responses all over 90 points and higher than normative population values.[22] De Pellegrin et al[13] found 25 complications in 398 patients (6.3%), including ankle joint effusion (8 patients), peroneal musculature contracture (14 patients), and stress fracture

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of the fourth metatarsal (3 patients). Pavone et al[14] had a mean follow-up of 58 months in 136 feet treated with SESA and outcomes including American Orthopedic Foot and Ankle Society (AOFAS) Ankle–Hindfoot score, the Oxford Ankle Foot Questionnaire for Children (OxAFQ-C)19, and the Foot & Ankle Disability Index (FADI) and FADI Sport scores. All patient-based outcomes improved significantly both 1 and 3 years after surgery compared with preoperative values.[14] Complications reported in 17 patients (of 68 patients, 25%) including pain at surgical scar (9 patients), screw loosening (3 patients), superficial infections (4 patients), and screw breakage (1 patient).[14] There has been no reported cartilage damage in patients undergoing SESA.

This study also compares the clinical and radiographic data of the SESA procedure to the traditional standard of MER. This is the first study, to our knowledge, to compare SESA with the standard of MER. Our study indicates an easier peri-operative course, earlier return to activities, and noninferior radiographic correction to MER. Prior studies on minimally invasive techniques, for example, the traditional intra-articular subtalar arthroereisis, had promising results to treat PPV, but with subsequent data reporting high complications. De Pellegrin and colleagues assessed a group of patients who underwent intra-articular subtalar arthroereisis with endorthesis and those with SESA. The authors found that SESA leads to lower rate of complications presumably because the "stop screw" is placed into the calcaneus itself to prevent excessive talo-calcaneal mobility, rather than being placed across the subtalar joint.[23] Traditionally, the standard treatment for patients with PPV in the United States has been with osteotomies such as the MER. The value of our study is that it offers clinicians comparative radiographic data as well as a clinical outcome perspective of the SESA technique in correcting PPV. Further, our study is one-off in offering data on reduced operative time with SESA compared with traditional techniques by $>70\%$, which could offer insight into the value of the procedure compared with traditional techniques.

This study has limitations, some are inherent in the retrospective nature of the study. While all patients were treated at a single institution, there were temporal differences in treatment (MER were done from 2010 to 2022, while SESA were done from 2019 to 2022), which could have affected our postoperative clinical course and led to more pronounced differences being found. Further, we did not collect patient-reported outcomes and thus were unable to correlate radiographic findings and clinical course to functional outcomes; ultimately, this remains the goal of treatment for PPV. Lastly, while we have reasonable follow-up on patients who underwent the SESA technique, our study lacks sufficient data to evaluate long-term correction after the hardware has been removed and compare those outcomes to traditional osteotomies. We would need 5 to 10 years posttreatment evaluation of our SESA population to ensure that the correction is maintained. Our group intends to continue to follow patients after implant removal for maintenance of correction and continued clinical function.

The goal of treating PPV remains to improve the function of patients and enable them to go back to their activities without limitations. Further studies looking into long-term outcomes of patients both radiologically and functionally using PROs would be helpful to establish the long-term efficacy of the SESA technique. Furthermore, ongoing assessment of the SESA technique and effectiveness can hone in on the ideal indications of the SESA technique. More studies in the future can help create a treatment algorithm for clinicians to use in the management of patients with PPV that reflects the value of care for any given patient.

CONCLUSIONS

Treating painful pediatric pes planovalgus (PPV) utilizing subtalar extra-articular screw arthroereisis (SESA) offers a less invasive approach with noninferior outcomes compared with the standard modified Evans reconstruction (MER) technique. Our study found that adolescents treated with SESA achieved similar radiographic improvements and deformity correction as MER patients. In addition, SESA was associated with shorter procedures and earlier return to weightbearing, with no major complications observed. Long-term follow-up and patient-reported outcome studies are warranted, particularly after screw removal.

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