REALIGNMENT CONSIDERATIONS WITH THE DOUBLE CALCANEAL OSTEOTOMY

Alan R. Catanzariti, DPM, FACFAS
Robert W. Mendicino, DPM, FACFAS
Glenda L. King, DPM
Brian Neerings, DPM

Calcaneal osteotomies have been recommended for surgical management of the flexible flatfoot deformity.[1-5] The authors have combined anterior calcaneal distraction and posterior calcaneal displacement osteotomies for surgical management of adolescent flatfoot and late stage II posterior tibial tendon dysfunction in the adult as defined by Johnson and Strom in 1989.[6] Lateral column distraction has been shown to reduce both hindfoot valgus and forefoot abduction by stabilizing the midtarsal joint. The posterior calcaneal displacement osteotomy, which results in medial translation of the calcaneal tuberosity, converts the posterior muscle group from an everter to an invertor during the propulsive period of the gait cycle and creates an active supinatory moment about the subtalar joint. This results in supination during the midstance phase of gait.[7,8]

This combination of procedures (the double calcaneal osteotomy or DCO) is considered when calcaneal valgus, forefoot abduction, and midtarsal joint instability are clinically significant. The deformity must be flexible with no radiographic evidence of degeneration involving the tritarsal complex.[1-4] The goals of the procedure are to restore anatomic realignment, stabilize the midtarsal joint, decrease pain, and improve function. These goals can be achieved without arthrodesis procedures and, therefore, the tritarsal joint complex is spared thus maintaining a supple, mobile foot that can adapt to ground reactive forces. The authors assess realignment by using preoperative, intraoperative, and postoperative radiographs. Antero-posterior (AP) and lateral (LAT) radiographs are used to evaluate alignment of the forefoot to the hindfoot. Additionally, hindfoot alignment (HA) and long leg calcaneal axial (LLCA) radiographs are used to further evaluate the alignment of the calcaneus to the tibia and to the ground in the frontal plane.

The long leg calcaneal axial view is similar to a standard calcaneal axial view but is taken on a longer cassette so that more of the tibia can be viewed. The x-ray beam is angled at 45 degrees and a 17 inch cassette is used. The alignment of the calcaneus, subtalar joint, and tibia can thus be evaluated. The axis of the calcaneus should be parallel but 5-10 mm lateral to the mid-diaphyseal axis of the tibia.[9] The authors routinely use this view during evaluation. The hindfoot alignment view is also used to assess frontal plane alignment and is more representative of the weightbearing alignment of the calcaneus to the tibia.[10] Additionally, the ankle joint is visualized in this view.[9,10]

The malleolar valgus index (MVI), as originally described by Song, et al, is used to assess static foot function in all patients (Figures 1, 2).[11]

MATERIALS AND METHODS

The authors prospectively reviewed 9 feet in 8 patients from the Foot and Ankle Institute at the Western Pennsylvania Hospital (WPH) from 2000-2002 with postoperative follow-up at 12 months. Eight patients with nine flatfeet were included in the study. The average age of the two males (3 feet) and six females (six feet) was 33 years (range, 15-60 years).

Surgical Technique

The surgery was performed under general or spinal anesthesia with a pneumatic thigh tourniquet. The surgical technique for the posterior calcaneal displacement osteotomy involves an oblique incision placed on the posterolateral aspect of the heel beginning at a point approximately two centimeters anterior to the Achilles tendon and one centimeter posterior to the tip of the lateral malleolus (Figure 3). The incision is extended at a 45-degree angle to the weight-bearing surface in an anterodistal direction to a point just inferior to the calcaneal border. Dissection is subperiosteal. Dissection is carried out posterior to the posterior facet of the subtalar joint along the dorsal aspect of the calcaneus and just

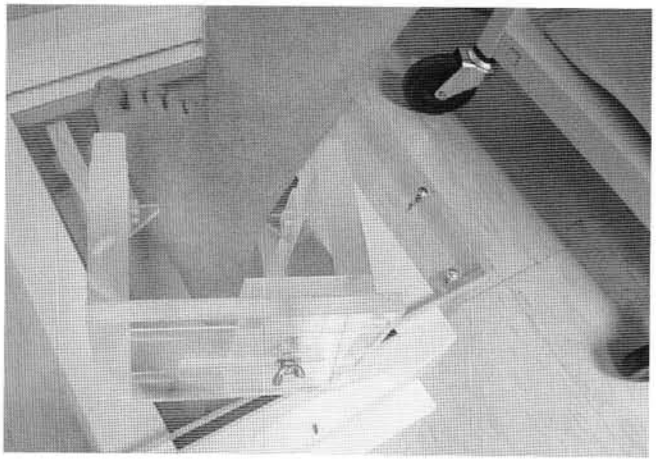

Figure 1. Malleolar valgus index jig.

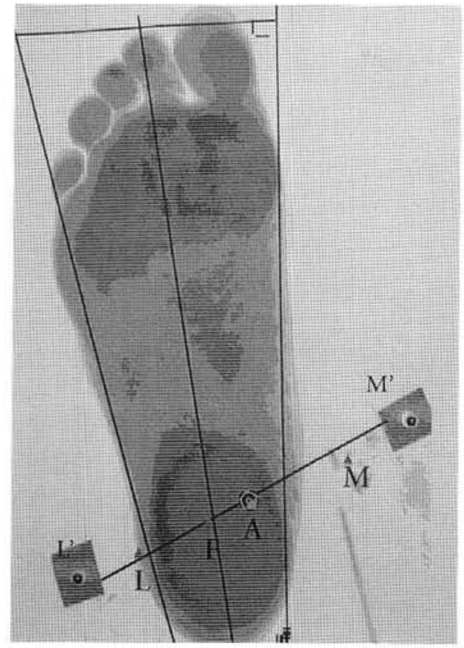

Figure 2. Scanned image of foot with measurement for MVI calculation. MVI (%) [(LA-LF)/LM] * 100 where LA = the distance between the lateral malleolus (L) and the malleoli bisection (A), LF = the distance between the lateral malleolus (L) and the foot bisection (F), and LM equals the distance between the lateral malleolus (L) and the medial malleolus (M).[11]

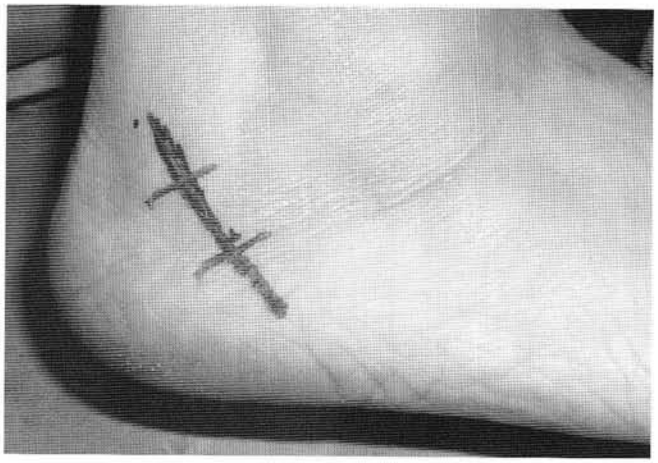

Figure 3. Incision placement for the PCDO. The incision passes at a 45 degree angle to the weightbearing surface in an anterodistal direction.

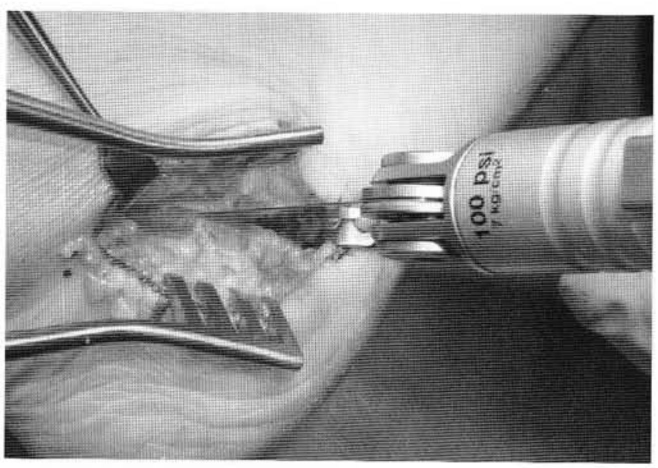

Figure 4. The sagittal saw is placed perpendicular to the lateral wall of the calcaneus and is in line with the skin incision.

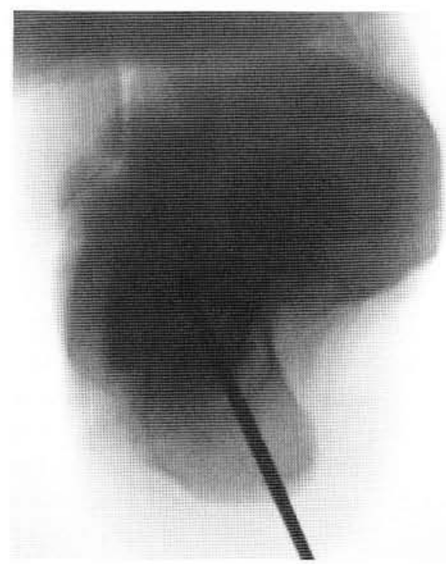

Figure 5. Intraoperatively, image intensification demonstrates the medial shift of the tuber segment.

Figure 6. Image intensification demonstrates final screw placement.

anterior to the plantar tubercle along the inferior aspect. An oblique transcortical osteotomy is performed with a sagittal saw (Figure 4). The osteotomy is kept perpendicular to the lateral wall of the calcaneus and in the same orientation as the skin incision. The tuber segment is then translated medially 1.0-1.5 centimeters, and image intensification is utilized to evaluate the correction and alignment before fixation is delivered[7,12] (Figure 5). Compression screws are used to fixate the osteotomy (Figure 6). Alternatively, Steinman pins are used when growth plates are open.

The incision for the anterior calcaneal osteotomy is placed in an oblique fashion distal to the sinus tarsi and 1.0-1.5 centimeters proximal to the calcaneocuboid joint (Figure 7). Care is taken to protect and retract the sural nerve and peroneal tendons. The periosteal incision is performed in a vertical fashion at the level of the planned osteotomy, one centimeter proximal to the calcaneocuboid joint. Image intensification may be used to confirm the level of the osteotomy (Figure 8). Dissection is subperiosteal with care taken to preserve the periarticular ligaments of the calcaneocuboid joint intact. The osteotomy is then performed with the sagittal saw oriented perpendicular to the lateral surface of the calcaneus and perpendicular to the weight-bearing surface (Figure 9). The medial cortex may be kept intact. The osteotomy is distracted to the desired position with the

Figure 7. Incision placement for the anterior calcaneal osteotomy is placed in an oblique fashion distal to the sinus tarsi and 1.5 cm proximal to the calcaneocuboid joint.

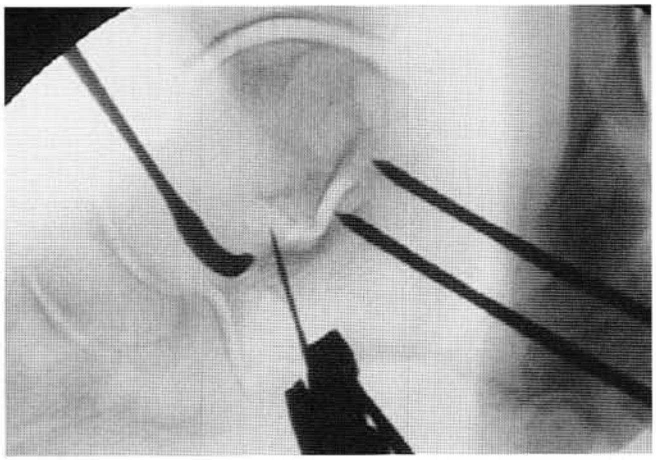

Figure 8. Image intensification is used intraoperatively to ensure proper placement of the osteotomy 1-1.5cm proximal to the calcaneocuboid joint.

Figure 9. The sagittal saw is placed perpendicular to the lateral wall of the calcaneus and to the weightbearing surface.

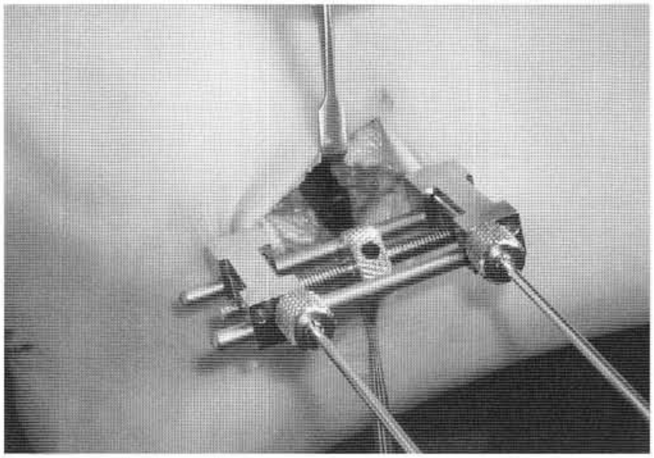

Figure 10A. A mini external fixator device is used to distract the osteotomy.

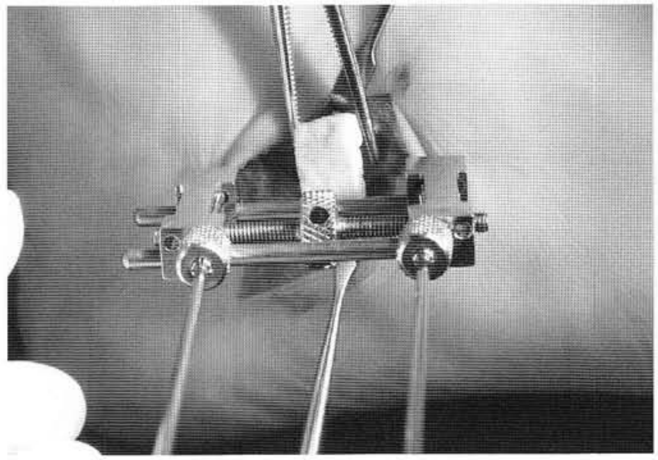

Figure 10B.

Table 1

PATIENT PROFILE

Patient	Age	Sex	Side	Ancillary Procedures	Complications
1	49	F	R	TAL, PTT repair, FDL transfer, DMO	Lymphedema R/O DVT
2	13	F	L	TAL	None
3	33	M	L	TAL, 1st metatarsal crescentic osteotomy	None
4	54	F	L	TAL, PTT repair, FDL transfer	None
5	60	F	R	TAL, PTT repair, FDL transfer	Painful fixation
6	16	M	L	TAL, Cotton osteotomy	Painful fixation
7	15	M	R	TAL	None
8	15	F	R	TAL, Cotton osteotomy	None
9	43	F	L	TAL, PTT repair, FDL transfer	Painful fixation, Transient sural neuritis

aid of a lamina spreader or external distracter (Figure 10). A trapezoid shaped allograft is inserted (Figure 11). Image intensification is used to ensure proper graft placement and realignment. Fixation is optional.[13]

All patients underwent a posterior muscle group lengthening. Other ancillary procedures included posterior tibial tendon repair (4 patients), flexor digitorum longus transfer (4 patients), medial cuneiform plantarflexory (Cotton) osteotomy (2 patients), distal first metatarsal osteotomy (1 patient) and proximal first metatarsal osteotomy (1 patient) (Table 1).

All patients were placed in a nonweightbearing fiberglass cast until both calcaneal osteotomies were radiographically healed or demonstrated consolidation at the host-graft interface (on average between 6-8 weeks). Patients were then placed in a fracture brace and gradually returned to full weightbearing.

Forefoot to hindfoot positioning was evaluated in all patients on standard AP (transverse plane assessment) and lateral (sagittal plane assessment) radiographs (Figures 12-15). The AP talo-first metatarsal angle was measured for transverse plane alignment (0 degrees = a parallel forefoot-to-hindfoot position), while the lateral talo-first metatarsal angle was measured for sagittal plane alignment (0 degrees = perpendicular forefoot to hindfoot position). The talocalcaneal angle was also measured on both the AP and the lateral radiographs. Other radiographic measurements included the calcaneal inclination angle, the talar declination angle, and the height of the medial cuneiform to the ground.

Evaluation of the hindfoot-to-leg and hindfoot-to-ground relationships in the frontal plane were evaluated using hindfoot alignment and long leg calcaneal axial radiographs (Figures 16-19). Additionally, the MVI was used to assess static foot function (Figures 20-21). All angular relationships were measured using the X-CaliperTM digital measuring device (Eisenlohr Technologies, Davis CA).

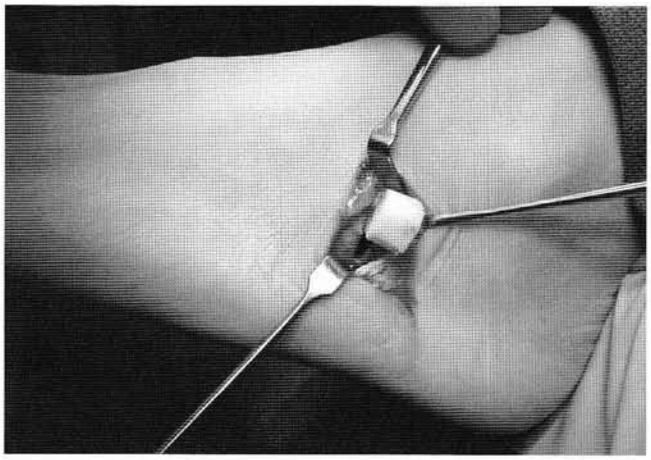

Figure 11. A trapezoidal shaped allograft is inserted into the distracted osteotomy site.

Figure 12. Preoperative AP view of the foot demonstrates an increased talo-first metatarsal angle and talocalcaneal angle.

Figure 13. One year after surgical correction these angles are corrected.

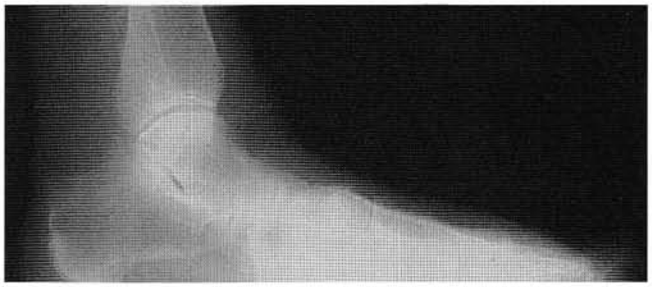

Figure 14. Preoperative lateral view of the foot demonstrates increased talo-first metatarsal, talocalcaneal, and talar declination angles. Additionally, the calcaneal inclination angle and medial cuneiform to ground height are decreased.

Figure 15. One year after surgical correction all measurements are improved.

Figure 16. Preoperative hindfoot alignment view. There is a lack of deformity at the ankle joint, but a significant valgus deformity in the hindfoot.

Figure 17. The calcaneus is in a more vertical position one year after surgical correction.

Figure 18. The preoperative long leg calcaneal axial view demonstrates a calcaneal valgus deformity in the weightbearing position.

Figure 19. The hindfoot deformity is corrected in the long leg calcaneal axial view taken one year following surgical intervention.

Figure 20. Preoperative MVI shows a significant pes planovalgus deformity in static stance.

Figure 21. A more rectus foot type in static stance is demonstrated one year following surgery.

RESULTS

All angles were measured pre-operatively and one year post-operatively on the anteroposterior, lateral, hindfoot alignment, and long leg calcaneal axial radiographs (Table 2). Statistical significance was calculated using a two tailed student t-test with an ? value of 0.05. The differences between the pre and postoperative values were found to be statistically significant in all angles measured. The mean AP talo-first metatarsal angle decreased from 11.9 to 2.3 degrees with a $P = 0.001$, and the lateral talo-first metatarsal angle improved from a mean of 24.8 to 3.7 degrees ($P <0.001$). Furthermore, the change in the talocalcaneal angle on both the AP and lateral views were statistically significant with a p-value of <0.001 and <0.002, respectively.

The calcaneal inclination angle increased ($P <0.022$), the talar declination angle decreased ($P <0.001$), and the cuneiform to ground height increased ($P <0.002$) in all patients. Realignment of the hindfoot to both the tibia and the weightbearing surface was also restored in all patients with a mean correction of 12.2 and 11.8 degrees, respectively. At one year follow-up, no calcaneocuboid joint changes were visualized on x-ray.

Additionally, static foot function, evaluated using the malleolar valgus index, also improved in all patients. The malleolar valgus indices are reported in Table 3. All patients achieved a more rectus foot type following surgery.[11]

Three patients had painful hardware removed, one patient suffered from a deep peroneal neuritis which had resolved at one year follow-up, and one patient has persistent lymphedema. A doppler ultrasound was performed on this patient two months post-operatively to rule out a deep vein thrombosis (Table 1). All patients are satisfied with their results and would have the surgery again.

DISCUSSION

Koutsogiannis described the treatment of the flexible flatfoot by a medial displacement osteotomy of the calcaneus.[4,7,8] This procedure consisted of a transcortical osteotomy of the calcaneus with medial transposition of the posterior tuberosity. This osteotomy restores the posterior muscle group function as a heel invertor by displacing the insertion of the achilles tendon from lateral to medial in relation to the subtalar joint axis thereby increasing the supinatory action during the midstance phase of gait. In addition, the ground reactive forces are displaced medially in relation to the subtalar joint axis with medial translation of the plantar tubercle resulting in a supinatory moment at heel strike.[1-5,7,8] Therefore, the posterior calcaneal displacement osteotomy significantly decreases the valgus deformity of the calcaneus and aids in supporting the medial longitudinal arch.[4]

Evans described an osteotomy at the anterior aspect of the calcaneus approximately 1.0 centimeter proximal

Table 2

PRE- AND POST-OPERATIVE MEASUREMENTS

Patient	Angle	AP talo-1st	AP talo-calc	Lat talo-1st	Lat talo calc	Calc inc	Tal dec	Cunei-gr ht	Cal-ground	Tibio-calc
1	Pre	8	24	21	50	11	38	2	18 vargus	13 valgus
	Post	2	16	4	35	22	14	4.8	2 vargus	4 valgus
		6	**8**	**17**	**15**	**11**	**24**	**2.8**	**16**	**9**
2	Pre	13	31	28	52	10	42	1.3	16 vargus	18 valgus
	Post	2	17	4	40	18	22	2.7	2 vargus	3 valgus
		11	**14**	**24**	**12**	**8**	**20**	**1.4**	**14**	**15**
3	Pre	10	29	23	56	10	39	1	6 vargus	4 valgus
	Post	3	14	4	35	23	26	2.7	rectus	rectus
		7	**15**	**19**	**21**	**13**	**13**	**1.7**	**6**	**4**
4	Pre	13	18	15	52	16	36	2.1	12 vargus	11 valgus
	Post	0	12	1	40	22	18	3	1 valgus	rectus
		13	**6**	**14**	**12**	**6**	**18**	**1.8**	**11**	**11**
5	Pre	12	21	32	62	13	44	0.6	20 valgus	23 valgus
	Post	3	14	11	39	21	25	1.7	2 valgus	2 vargus
		9	**7**	**21**	**23**	**8**	**19**	**1.1**	**18**	**21**
6	Pre	13	18	25	52	10	42	0.9	8 valgus	10 valgus
	Post	3	8	1	43	18	25	2.4	1 vargus	rectus
		10	**10**	**24**	**9**	**8**	**17**	**1.5**	**7**	**10**
7	Pre	16	26	27	63	9	50	1.8	16 valgus	14 valgus
	Post	1	16	8	42	19	25	2.8	rectus	2 valgus
		15	**10**	**19**	**21**	**10**	**25**	**1**	**16**	**12**
8	Pre	12	32	26	60	22	45	1.2	18 valgus	20 valgus
	Post	3	16	0	38	11	22	2.4	3 valgus	4 valgus
		9	**16**	**26**	**22**	**11**	**23**	**1.2**	**15**	**16**
9	Pre	10	25	26	54	12	42	1.5	8 vargus	6 valgus
	Post	4	12	0	38	18	20	2.5	2 valgus	rectus
		6	**13**	**26**	**16**	**6**	**22**	**1**	**6**	**6**
Mean	Pre	11.9	24.9	24.8	55.6	12.6	42	1.4	13.6 vargus	13.2 valgus
	Post	2.3	13.9	3.7	38.9	19.1	21.9	2.8	1.4 vargus	1.4 valgus
		9.6	**11**	**21.1**	**16.7**	**6.5**	**20.1**	**1.4**	**12.2**	**11.8**

to the calcaneocuboid joint.[13] A bone graft is placed into the osteotomy site effectively lengthening the lateral column and stabilizing the midtarsal joint. Lengthening of the lateral column creates a "bowstringing" effect that may be responsible for clinical restoration of the longitudinal arch.[14] Lateral column lengthening will reduce inversion demand on the posterior tibial tendon and reduce the achilles force required to achieve the heel rise position.[15,16] In Evan's original paper, no fixation was used at the osteotomy site.

The combination of the posterior calcaneal displacement osteotomy and the anterior calcaneal distraction osteotomy has been evaluated in the literature.[1-3] These procedures have been utilized at our institution for the adolescent patient with a painful flexible flatfoot and the adult patient with late stage II posterior tibial tendon dysfunction.[7] The double calcaneal osteotomy may be used in the patient with significant midtarsal joint and subtalar joint instability. The procedure is ideal when severe midtarsal joint and subtalar joint deformities exist but remain reducible.[2] Isolated subtalar joint or triple arthrodesis should be performed in the nonreducible deformity with radiographic evidence of degenerative changes in the tri-tarsal complex.[1-5,7,8] The combination of these two osteotomies will correct severe deformities in the transverse, frontal, and sagittal planes at both the midtarsal and subtalar joints with less severe displacements at both osteotomy sites.[3]

The authors have evaluated 9 feet in 8 patients who underwent a double calcaneal osteotomy procedure. The patients' radiographs and malleolar valgus indices were evaluated for correction and realignment (Table 1). Forefoot to hindfoot, hindfoot to leg, and hindfoot to ground correction were maintained at one-year follow up in all patients. The midtarsal joint also remained clinically stable in all patients. There was no evidence of degeneration at the calcaneocuboid joint in any of the cases.

The small number of patients and short term follow up are limitations of the study. The study is ongoing and longer term results with a larger number of patients will be reported in the future.

CONCLUSION

The authors' purpose is to emphasize the importance of lower extremity realignment and joint-sparing procedures for surgical management of the flexible flatfoot deformity. Using radiographic analysis, the authors have shown that the double calcaneal osteotomy procedure can be successful in reestablishing proper realignment in the flexible flatfoot deformity. Periarticular osteotomies obviate the need for arthrodesis procedures and therefore maintain the mobile, adaptive nature of the tritarsal complex during gait. Additionally, accurate realignment without arthrodesis will decrease the incidence of degeneration within the ankle over the long term.

Table 3

MALLEOLAR VALGUS INDICES

Patient		MVI1	MVI 2
1	Pre	35.3%	32.4%
	Post	11.8%	15.0%
2	Pre	50.0%	46.4%
	Post	28.6%	32.1%
3	Pre	38.2%	38.2%
	Post	3.1%	6.3%
4	Pre	29.4%	28.1%
	Post	5.6%	2.8%
5	Pre	48.1%	53.9%
	Post	19.2%	26.9%
6	Pre	35.3%	35.3%
	Post	7.1%	6.3%
7	Pre	30.6%	38.2%
	Post	18.8%	23.3%
8	Pre	64.3%	64.3%
	Post	34.4%	31.3%
9	Pre	21.9%	27.3%
	Post	14.3%	12.1%

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