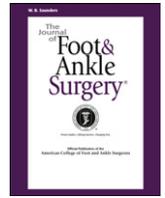




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Original Research

A Retrospective Analysis of Anterior Calcaneal Osteotomy with Allogenic Bone Graft

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ABSTRACT

Anterior calcaneal osteotomy (ACO) with extension bone graft is commonly employed in the treatment of symptomatic supple, hypermobile flatfoot in adolescent as well as adult (≥ 18 years of age) patients. Although autogenous bone graft has been considered the gold standard, allogenic bone is widely used for this procedure because it is readily available, requires no additional procedure for procurement and has incorporation rates similar to autogenous bone graft. There is increasing agreement among surgeons that the union rates with allograft bone are comparable with that observed with autograft bone when used in the ACO. We reviewed the medical records of 51 consecutive patients who had undergone 53 ACO with allogenic bone graft for the repair of flatfoot deformity in an effort to further evaluate outcomes associated with the use of allogenic bone graft. All of the patients had at least 12 months of follow-up. The mean time to graft incorporation was 9.10 ± 1.54 weeks for adolescents and 9.81 ± 2.13 weeks for adults ($P = .0149$). The incidence of graft incorporation (bone union) was 100% and 90% ($P = .1391$) in the adolescent and adult groups, respectively. Complications included lateral column pain, sinus tarsi, nonunion, calcaneocuboid capsulitis, complex regional pain syndrome, incisional dehiscence, and sural neuritis; and all of the complications occurred in the adult group. The results support the understanding that ACO with allogenic bone graft is a reasonable alternative to autograft bone graft in the treatment of flexible flatfoot in adolescent and adult patients.

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The anterior calcaneal osteotomy (ACO), specifically the Evans procedure, is a commonly performed operation for the treatment of supple adolescent and adult flatfoot deformity that fails non-operative care (1, 2). Evans originally described treatment of calcaneovalgus deformity with lateral column lengthening using autogenous tibial cortical bone graft (3). Although autograft remains the standard choice of biomaterial, allogenic bone has also been used with success. In fact, allogenic bone allograft has the advantage of being widely available and does not require an additional operative procedure to procure the graft, and, perhaps most importantly, the prevalence of satisfactory bone incorporation with the use of allogenic bone has

been shown to be similar as that for autograft (4). Despite some fears of disease transmission associated with allogenic bone graft use, only a few cases have actually been reported (5–7), and each of these occurred in the 1980s, when the American Society of Tissue Banks' safety protocols and standards were considered to be less stringent. In general, allogenic bone has proven to be safe for grafting, and many surgeons prefer allogenic bone to extend the lateral column of the foot in conjunction with osteotomy of the anterior portion of the calcaneus (8). In an effort to further assess outcomes associated with the use of allogenic bone graft combined with ACO, we undertook a retrospective cohort study of adolescent and adult patients with supple symptomatic flatfoot deformity treated by means of surgical reconstruction.

Patients and Methods

The medical records and radiographs of consecutive adolescent (< 18 years of age) and adult (≥ 18 years of age) patients who had ACO with implantation of a freeze-dried allogenic bone graft for the surgical management of supple symptomatic flatfoot

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deformity between January 2003 and July 2007 (approximately 4.5 years) were reviewed. All of the cases reviewed have at least 12 months of follow-up from the time of the operation. Patients with a history of previous flatfoot surgery, tobacco smoking, diabetes mellitus, osteonecrosis or metabolic bone disease, or chronic corticosteroid use were excluded from the investigation. Graft incorporation and bone union were defined as the radiographic appearance of trabeculation across the host-graft interface, as determined by consensus of the authors. The demographic results, including complications related to the procedure, were abstracted from the records, stored in a personal computer, and then analyzed with Stata/SE 9.2 for Macintosh (Stata Corporation, College Station, TX). For the purposes of the investigation, statistical significance was defined at the 5% ($P \leq .05$) level.

Surgical Procedure

The patient was placed supine on the operating table with a bump placed beneath the ipsilateral buttock to medially rotate the foot. A pneumatic thigh tourniquet was typically used for hemostasis. An oblique (Figure 1) or a curvilinear incision was placed distal to the sinus tarsi and 1 to 1.5 cm proximal to the calcaneocuboid joint (Figure 1). This approach usually avoids the dorsal cutaneous nerves and provides access to the lateral wall of the anterior portion of the calcaneus, although care must be taken to protect the peroneal tendons and the sural nerve. An image intensifier was sometimes used to confirm the osteotomy location prior to execution (Figure 1). Once satisfied with the location, periosteum was incised in a vertical fashion, and an elevator was used to dissect periosteum from the lateral wall of the calcaneus. Periarticular dissection was limited to avoid destabilization of the distal segment. A sagittal saw blade was oriented perpendicular to the lateral surface of the calcaneus and perpendicular to the weight-bearing surface (Figure 2) to initiate the osteotomy in a lateral-to-medial direction, and a handheld osteotome

was typically used to complete the cut without violating the medial osseous hinge and soft tissue structures. A lamina spreader, or a mini-distractor (Figure 3), was then used to manipulate and distract the osteotomy to the desired length to achieve restoration of arch height. The precise degree of correction was determined intraoperatively with fluoroscopy in conjunction with direct visualization of the sagittal, frontal, and transverse plane orientations of the foot, and the allograft bone wedge was sized to fit the corrected alignment. Freeze-dried tricortical allograft is ideally suited for optimal distraction of the lateral column. The graft was fashioned into a triangular or trapezoidal wedge, with its cortical base measuring 7 to 10 mm in width. The cortical base was oriented lateral and apex medial, and then tamped into its final position (Figures 4 to 6). The allograft remained secure without the need for fixation. After completion of any adjunct surgical procedures and application of a surgical dressing, a short-leg, non-weight-bearing cast was used for 6 to 8 weeks, and serial radiographs were obtained to determine the status of graft incorporation. As soon as clinical and radiographic signs of healing were noted, the patient was transitioned to full weight bearing in a short-leg walker-boot that immobilized the ankle, after which a gradual transition to an athletic shoe was undertaken.

Fixation was not utilized in any of the cases in this series. The bone graft is secured in position by the compression generated with lateral column lengthening. The bone graft should be thoroughly evaluated for stability and fixation should be employed for those grafts considered unstable. It is critical that no motion is present at the host-graft interface such that rapid incorporation takes place. However, the authors believe that the standards for ACO have changed over the last several years and currently fixate these on a routine basis.

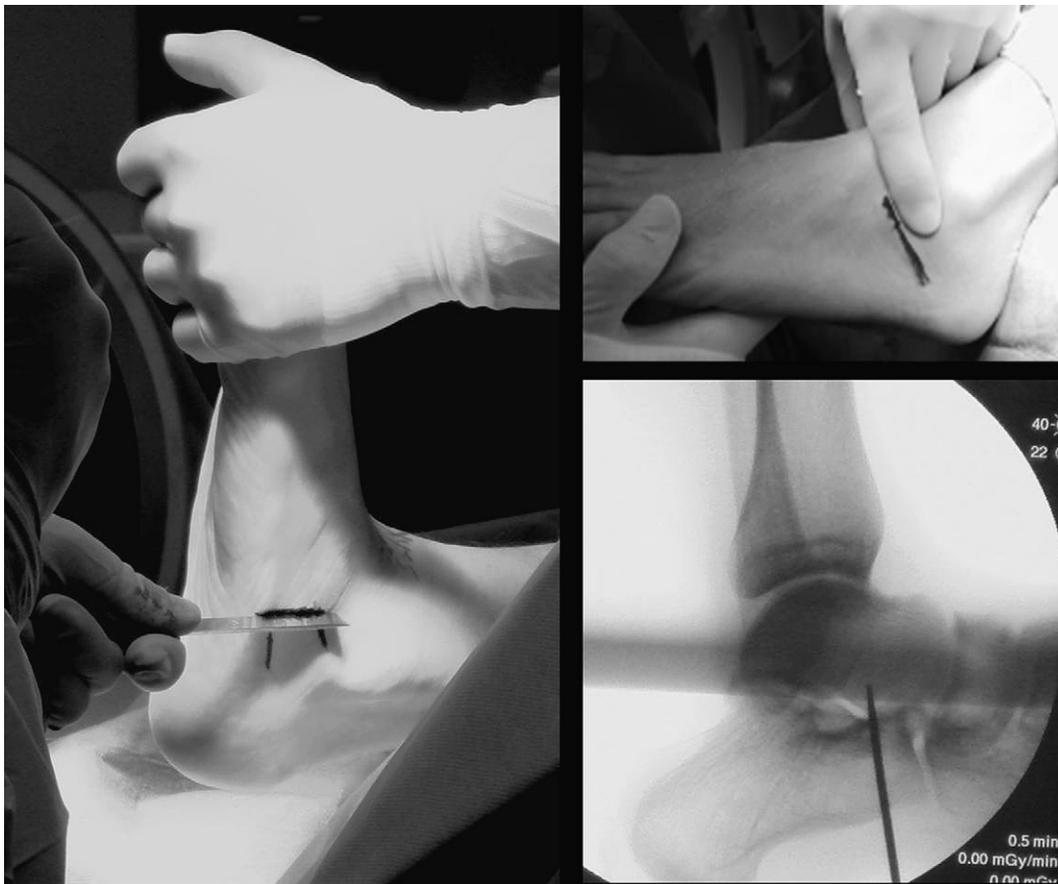


Fig. 1. The incision is placed distal to the sinus tarsi and 1 to 1.5 cm proximal to the calcaneocuboid joint (top right image) to avoid the dorsal cutaneous nerves while gaining access to the lateral wall of the anterior portion of the calcaneus. An image intensifier can be used to confirm the location of the planned osteotomy before execution (left and bottom right images).



Fig. 2. A sagittal saw blade oriented perpendicular to the lateral surface of the calcaneus and perpendicular to the weight-bearing substrate is used to initiate the osteotomy in a lateral-to-medial direction, with care taken to avoid violation of the medial osseous hinge and soft tissue structures.

Results

A total of 34 adults (34 feet) and 21 adolescents (23 feet) were found to be eligible for inclusion in the cohort; however, 4 adult patients, including 1 man and 3 women, accounting for 7.84% of the patients and 4 (7.55%) of the operated feet, were lost to follow-up for

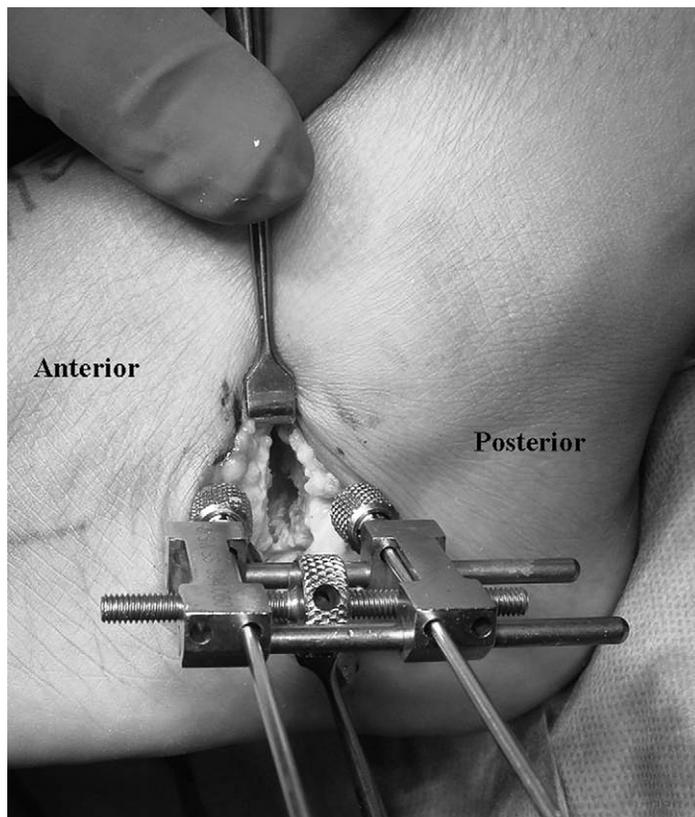


Fig. 3. A mini-distractor (or a lamina spreader) is used to manipulate and distract the osteotomy to the desired length to achieve restoration of arch height.

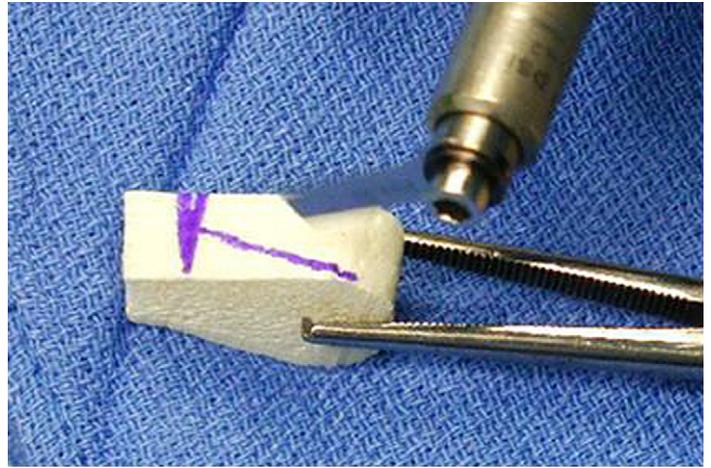


Fig. 4. A freeze-dried tricortical corticocancellous allograft is fashioned to the precise configuration, which is determined at the time of the operation.

random reasons and were not included in the analyses. The cohort, therefore, consisted of 53 feet in 51 patients who had undergone ACO with placement of an allogenic bone graft, with at least 12 months of follow-up. A statistical description of the cohort is depicted in Table 1. The adolescent group consisted of 23 feet in 21 patients, including 8 women and 13 men, with a mean age of 13.24 ± 1.77 years. One patient in the adolescent group underwent bilateral anterior calcaneal osteotomy with allogenic bone graft on separate occasions during the observation period. The adult group consisted of 30 feet in 30 patients, including 7 men and 23 women, with a mean age of 47.37 ± 13.42 years. The adult group consisted of 23 (76.67%) women, whereas the adolescent group consisted of 8 (38.1%) women, and this difference was statistically significant ($P = .006$). Furthermore, graft incorporation, as determined by radiographic evidence of healing, took place in 9.81 ± 2.13 weeks in the adult group, whereas this required 9.10 ± 1.54 weeks in the adolescent group, and this difference was also statistically significant ($P = .0149$). All of the patients had failed non-operative care such as foot orthoses, prefabricated

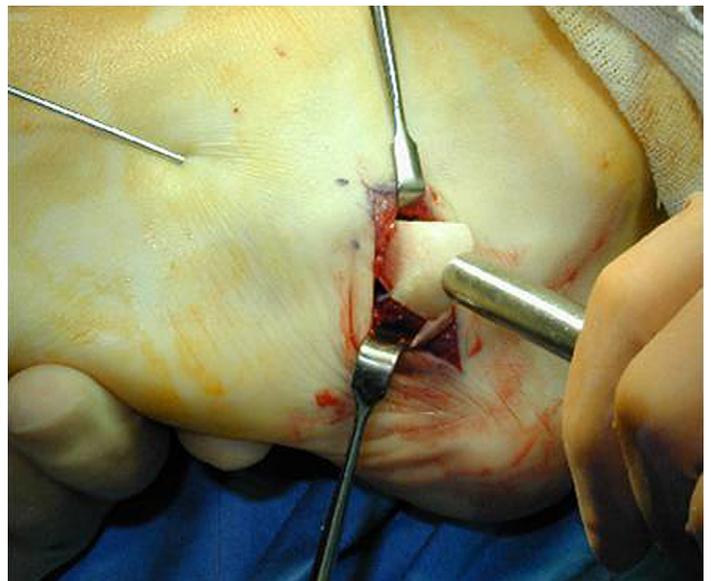


Fig. 5. A tamp is used to position the allograft securely in the osteotomy, taking care not to advance it too far medially or dorsally.

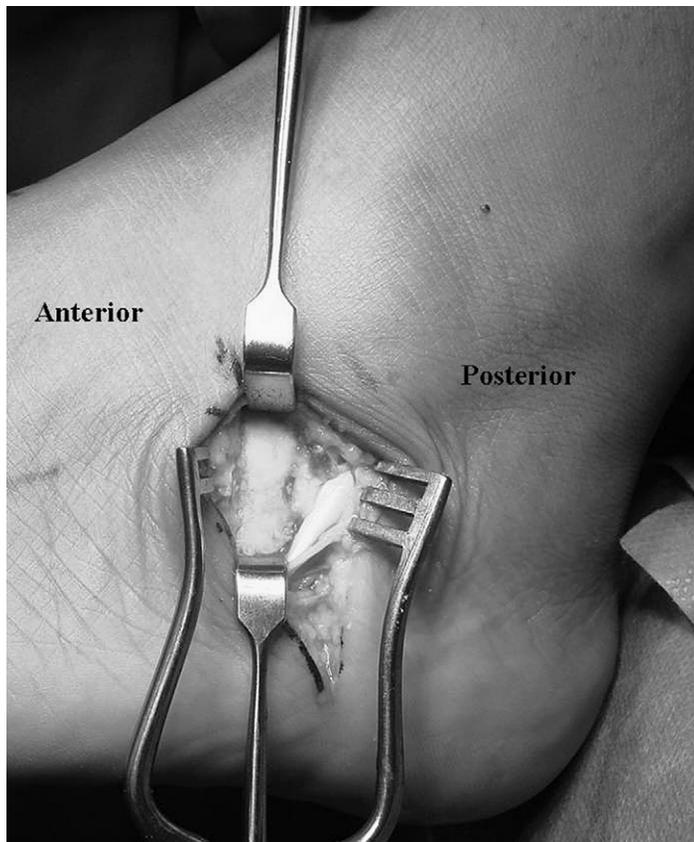


Fig. 6. In its final position, the allogenic bone graft advances the lateral column distally for 7 to 10 mm, with the lateral cortices of the graft and the distal and proximal portions of the calcaneus aligned so that they are flush.

and/or custom braces, and shoe gear modifications, as well as analgesic and anti-inflammatory medications and physical therapies before undergoing operative intervention. A number of ancillary procedures were utilized in these cases including tendo-Achilles lengthening (2 adolescents and 15 adults), gastrocnemius recession (21 adolescents and 15 adults), medializing calcaneal displacement

osteotomy (15 adolescents and 26 adults), calcaneonavicular coalition resection (1 adolescent), flexor digitorum longus to tibialis posterior tendon transfer (19 adults), and distal first metatarsal chevron osteotomy bunionectomy (1 adult) (Table 1). A total of 76 adjunct surgical procedures (2.53 per case) were undertaken in the adult group, whereas 37 (1.61 per case) were undertaken in the adolescent group, and this difference was statistically significant ($P = .0417$).

A total of 17 (56.67%) surgical complications were observed in the adult group, whereas none were observed in the adolescent group, and this difference was statistically significant ($P < .0001$) (Table 1). Complications included calcaneocuboid capsulitis, complex regional pain syndrome, incision dehiscence, and sural neuritis. There were no cases of allogenic bone graft displacement or resorption, or postoperative infection. Successful union was achieved in 27 (90%) of the adult cases and 23 (100%) of the adolescent cases. Three (10%) of the adult patients failed to display complete radiographic graft incorporation at the time of their final follow-up visit. One of these patients was asymptomatic had a computerized tomographic scan demonstrating partial bridging across the graft site. A second patient was also asymptomatic. However, the third patient was painful at the ACO site and required surgical revision with autogenous iliac crest graft, which proceeded to successful union within 3 months of the second operation. Four (13.33%) of the adult cases experienced sinus tarsitis, and 6 (20%) experienced lateral column pain that persisted beyond the time required to establish satisfactory bone healing. With the exception of the patient with sural neuritis, which required sural neurectomy to alleviate pain at the site of the calcaneal osteotomy, and the patient who required revisional surgery to repair the nonunion, all of the remaining adult patients experienced resolution of their postoperative complaints without the need for further surgery.

Discussion

Lateral column lengthening is a common procedure used for the surgical management of flexible adolescent and adult acquired flat-foot. It provides triplanar correction of hindfoot valgus, reconstitution of the longitudinal arch, and reduction of dorsolateral peritalar subluxation (3, 9, 10). Opening wedge ACO was initially described for the treatment of flexible pediatric pes planovalgus and is now also

Table 1

Statistical description of the cohort (N = 53 feet in 51 patients) (results depicted as mean \pm standard deviation, or count and percentage)

Variable	Adolescent group (n = 23 feet in 21 patients)	Adult group (n = 30 feet in 30 patients)	P value*
Age (y)	13.24 \pm 1.77	47.37 \pm 13.42	<.0001
Female sex [count (%)]	8 (38.1)	23 (76.67)	.0060
Time to radiographic union (wk)	9.10 \pm 1.54	9.81 \pm 2.13	.0149
Adjunct procedure			
Achilles tendon lengthening	2 (8.7)	15 (50)	.0028
Gastrocnemius recession	21 (91.3)	15 (50)	.0906
MCDO	15 (65.22)	26 (86.67)	.0782
Resection of CN coalition	1 (4.35)	0	.2320
FDL to TP tendon transfer	0	19 (63.33)	<.0001
Chevron bunionectomy	0	1 (3.33)	.4028
Complication			
Calcaneocuboid capsulitis	0	1 (3.33)	.4028
Complex regional pain syndrome	0	1 (3.33)	.4028
Allograft displacement/resorption	0	0	>.05
Incision dehiscence	0	1 (3.33)	.4028
Postoperative infection	0	0	>.05
Nonunion	0	3 (10)	.1391
Sinus tarsitis	0	4 (13.33)	.0844
Sural neuritis	0	1 (3.33)	.4028
Lateral column pain	0	6 (20)	.0308

Abbreviations: CN, calcaneonavicular; FDL, flexor digitorum longus; MCDO, medializing calcaneal displacement osteotomy; TP, tibialis posterior.

* Wilcoxon rank sum test.

used in reconstruction of the adult-acquired flatfoot (11–13). Tri-cortical bone graft, such as iliac crest, is ideal for this procedure because the cortical portion provides excellent structural support and the cancellous portion provides a trellis for osteoconduction. The iliac crest is a common site to harvest autogenous bone graft; however, allogenic bone graft also provides satisfactory structural support without the morbidity associated with procurement of an autograft. Mosca (14) described the use of tricortical iliac crest allograft with the Evans calcaneal osteotomy for correction of hindfoot valgus deformity, and reported no complications in 24 patients who were followed up over a 24- to 43-month period. Dolan et al (8) prospectively compared iliac crest autograft with allograft for correction of the adult-acquired flatfoot in 33 feet in 31 patients and reported no delayed unions, nonunions, or hardware failures among the 18 patients in the allograft group, and all of the patients displayed satisfactory bone healing by 12 weeks. Myerson et al (15) reported successful union in calcaneal osteotomies with fresh-frozen structural allografts for 11 feet with an average time to union of 10 weeks. Our union rates were comparable with those of the aforementioned studies. In comparison with these historical controls, the incidence of graft incorporation and satisfactory bone healing and the duration of time required to achieve bone healing were very similar to those observed in our cohort. It is also interesting to note that even though the duration of time required for allograft incorporation was statistically significantly ($P = .0149$) longer in our adult group, as compared with the adolescents (9.81 ± 2.13 weeks vs 9.10 ± 1.54 weeks, respectively), it is doubtful that this difference is clinically significant.

Several complications have been reported with the Evans procedure, including calcaneocuboid arthrosis, dorsal displacement of the anterior fragment, sural neuritis, and stress fracture of the fifth metatarsal (16). Complications specific to the bone graft include displacement, structural failure, and nonunion or delayed union. In our study, none of these complications occurred in the pediatric group, and no displacement or structural failure of the allograft was noted in any of our patients despite the lack of fixation. Historically, moreover, disease transmission has been of some concern with the use of allograft, despite the reported low risk of this occurrence (8). To our knowledge, there were no occurrences of disease transmission from the allograft material in our patient population.

All of the postoperative complications ($P < .0001$) were in our adult patient population, and most of these were related to symptoms associated with the lateral column. We are unsure if the isolated symptomatic nonunion was related directly to the use of allogenic bone graft. Still further, because all of the patients in our cohort had at least 1 ancillary procedure performed in addition to the ACO with allogenic bone graft, it is possible that the adjunct procedures may have been more responsible for the observed complications. In fact, it is likely that the combination of a medializing calcaneal displacement osteotomy and the Evans osteotomy with allograft, which was used in 15 (65.22%) of the adolescents and 26 (86.67%) of the adults, could substantially increase the chance that a complication, such as sural neuritis or sinus tarsi, would develop.

Like all retrospective cohort studies, the results of our investigation may have been threatened by a number of methodological limitations. Among these shortcomings was the fact that individuals involved with the operations also abstracted data from the medical records and interpreted the radiographs. Moreover, it is likely that interpretation of some of the information in the records may have been ambiguous and interpreted differently by different assessors. Furthermore, our decision not to include data from those lost to follow-up may have biased our results. Still further, from a statistical standpoint, we did not undertake explanatory analyses and therefore

were not able to determine the influence that the independent variables, alone or in conjunction with other variables, had on our outcomes. In fact, we may have failed to consider important variables that other surgeons would consider crucial to the assessment of repair of the flexible flatfoot. Finally, we realize that it is always questionable to compare results with historical controls, because the independent variables, including the interventions, often differ substantially between studies. Despite these limitations, we still feel that our findings show that, in adults and adolescents, the use of allogenic bone is safe and effective, even in conjunction with ancillary procedures used to correct the flexible flatfoot.

In conclusion, the results of this study are consistent with other studies reporting on the use of allogenic bone for an opening wedge anterior calcaneal osteotomy in the treatment of the flexible flatfoot deformity. Based on our findings in this investigation, we believe that allogenic bone graft is a safe and effective biomaterial for use with the ACO in adult and adolescent populations. The results of this investigation, moreover, could be useful to future investigators interested in designing randomized controlled trials and prospective cohort studies that focus on the use of lateral column lengthening by means of the Evans osteotomy with allogenic bone graft.

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