Autograft and Allograft Unite Similarly in Lateral Column Lengthening for Adult Acquired Flatfoot Deformity

J. Turner Vosseller, MD · Scott J. Ellis, MD · Martin J. O'Malley, MD · Andrew J. Elliott, MD · David S. Levine, MD · Jonathan T. Deland, MD · Matthew M. Roberts, MD

Received: 4 June 2012/Accepted: 5 November 2012 /Published online: 10 January 2013
© Hospital for Special Surgery 2013

Abstract

Background: Lateral column lengthening (LCL) is used to address the forefoot abduction associated with the adult acquired flatfoot. This opening wedge osteotomy can be filled with either allograft or autograft bone.

Questions/Purposes: The investigators sought to determine union rates and any loss of correction in patients undergoing LCL with autograft versus allograft.

Methods: Over a 3-year period, 126 LCLs performed by five surgeons in 120 patients were reviewed. Autograft was used in 51 patients, allograft in 75 patients. Times to clinical and radiographic union were established for these patients. Any loss of correction of forefoot abduction as manifested by talonavicular uncoverage was recorded for those grafts that healed. Failure was defined as nonunion or loss of 50% or greater correction. The size of the implanted graft was assessed as a risk factor for failure.

Results: There were 20 total failures: seven in patients with autograft and 13 in patients with allograft ($p=0.63$). The size of the implanted graft was larger in those patients that did fail ($p=0.04$).

Conclusions: The rate of nonunion and loss of correction for LCL was not significantly different between allograft and

autograft. The overall rate of nonunion may be higher than has previously been reported.

Keywords lateral column lengthening · adult acquired flatfoot deformity · posterior tibial tendon insufficiency/dysfunction · nonunion · loss of correction

Introduction

Adult acquired flatfoot deformity has been classified into three or four stages which help guide surgical decision making. The most variability in the surgical approach occurs in those patients with stage II (flexible, nonarthritic) deformity [18]. Stage II has been further subdivided into mild (<30% talonavicular uncoverage, IIa) and severe (>30% talonavicular uncoverage, IIb) [8, 24]. This subdivision is based on the amount of forefoot abduction manifested through the talonavicular joint as present on an anteroposterior, weight-bearing radiograph [9]. Lateral column lengthening (LCL), originally described by Evans [14], is used to specifically address the forefoot abduction that occurs in patients with stage IIb flatfoot deformity. In this procedure, an opening wedge osteotomy of the anterior process of the calcaneus is performed to correct the abduction. The osteotomy is commonly filled with either allograft or autograft bone.

Union rates in patients undergoing LCL for acquired flatfoot using either allograft or autograft bone have been reported in two studies [10, 16]. Both studies concluded that allograft bone was at least as effective in terms of healing as autograft. Given these findings, it would appear that allograft bone is preferred as it avoids potential morbidity associated with the iliac crest harvest [1, 15].

However, at the investigators' institution, nonunion and graft collapse has been noted in patients undergoing LCL with allograft. From our experience, we hypothesized that autograft would lead to both a higher union rate and decreased collapse

Level of Evidence: Therapeutic Study (Comparative retrospective study): Level III. See Levels of Evidence for a complete description.

J. T. Vosseller, MD · S. J. Ellis, MD · M. J. O'Malley, MD ·
A. J. Elliott, MD · D. S. Levine, MD · J. T. Deland, MD ·
M. M. Roberts, MD
Hospital for Special Surgery,
535 East 70th Street,
New York, NY 10021, USA

J. T. Vosseller, MD (✉)
Columbia University,
622 West 168th Street, PH-11, New York, NY 10032, USA
e-mail: turner.vosseller@gmail.com

as evidenced by loss of talonavicular correction. The purpose of this study was to compare the rate of union and the time to union in cohorts of patients undergoing LCL with allograft or autograft and to assess potential risk factors such as the use of bone marrow aspirate with allograft and the size of the allograft on rate of nonunion. In addition, the investigators wanted to calculate radiographic settling or collapse of the graft in those patients in whom union did occur.

Materials and Methods

Between January 1, 2006, and December 31, 2008, consecutive patients undergoing LCL for stage IIb flatfoot deformity were retrospectively assessed at a minimum of 12 months from surgery. These surgeries were performed by five fellowship-trained foot and ankle surgeons from the same institution. Tricortical iliac crest autograft or allograft was used in each case. The inclusion criterion was any patient that had LCL as part of a flatfoot correction. Patients who were younger than 18 years of age were excluded as it was felt they had a different healing capacity than most patients with an acquired flatfoot. Three surgeons exclusively used allograft bone, while two surgeons switched from allograft to autograft during the study period because of concerns about healing with allograft.

A series of 120 patients with 126 flatfoot reconstructions were identified; six patients had bilateral procedures. The average age at the time of surgery was 55.0 years. Fifty-one feet had autograft used for the LCL (mean age, 54.1), while 75 feet had allograft used for the LCL (mean age, 55.5).

The surgical technique utilized has been described previously [12]. Briefly, an Evans calcaneal lengthening osteotomy was performed through the anterior process of the calcaneus approximately 1.0 cm proximal to the calcaneocuboid joint. The calcaneocuboid joint was not provisionally pinned. The appropriately sized graft reduced talonavicular coverage without creating excessive eversion stiffness as assessed by manual exam intraoperatively. The fixation used varied among surgeons (Table 1), although all of the patients had some form of screw fixation. All of the patients in this study had other procedures performed along with the LCL (Table 2).

Table 1 LCL fixation

Fixation	Number of patients
Single 4.0-mm screw	48
One 2.7-mm screw and one 2.4-mm screw	32
Two 2.7-mm screws	21
Single 3.5-mm screw	11
Single 2.7-mm screw	6
One 2.7-mm screw and one 2.0-mm screw	3
One 3.5-mm screw and one 2.4-mm screw	1 each
Two 3.5-mm screws	
Two 2.7-mm screws and 2.4-mm plate	
Two 2.4-mm screws and staple	
One 4.0-mm screw and one 2.7-mm screw	

Table 2 Other procedures: procedures that were performed ten or more times are shown

Procedure	Times performed (of 126 feet)
Medializing calcaneal osteotomy	123
FDL transfer	120
Posterior tibial tendon debridement/excision	112
1st tarsometatarsal fusion	76
Gastroc recession	64
Spring lig. repair	58
TAL	55
FHL–FDL tenodesis	51
Modified McBride	26
Cotton osteotomy	21
Akin osteotomy	16
Excision accessory navicular	14
2nd MTP release, PIP rsxn, pinning	10

Iliac crest autograft was harvested using a standard technique. The allograft used was tricortical iliac crest in all cases. It was initially used in isolation. Three of the surgeons then switched to mixing and reconstituting the allograft in an aspirate from the iliac crest (bone marrow aspirate, BMA). Thirty of the 75 feet with allograft had the allograft used in isolation, while 45 feet had the allograft mixed with BMA.

Union rates of autograft and allograft were established. In the allograft patients, union rates were established for each set of patients, i.e., allograft alone and allograft with BMA. The size of the graft was recorded from the operative report for each patient and assessed as a risk factor for nonunion.

Times to clinical and radiographic union were assessed by review of the postoperative charts and radiographs, respectively. Clinical union was defined as the time at which the patient was able to bear full weight without pain. As this was a retrospective study, the clinical follow-up was done by the treating surgeon. Radiographic union was defined as osseous bridging at the osteotomy site as evident on plain radiographs. Radiographic assessment was performed by a fellowship-trained foot and ankle orthopedic surgeon blinded to the operating surgeon and whether the patient had autograft or allograft. Patients were typically seen and radiographs obtained at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year after surgery. The presence of a nonunion was judged based on clinical examination looking specifically for pain at the LCL site and difficulty with weight bearing. Nonunions were confirmed radiographically by review of the postoperative radiographs by a surgeon involved in the study who was blinded to the operative procedure. Median times to clinical and radiographic healing were established for the group as a whole, as well as for the allograft and autograft groups, respectively.

Radiographs were also reviewed for any loss of correction in those patients that healed by assessing the percent of talonavicular uncoverage on the first standing anteroposterior (AP) radiograph obtained after surgery [23]. This coverage was then compared with the standing AP radiograph at final follow-up. Any loss of this coverage was then

measured simply as either 0, 25, 50, 75, or 100%. Loss of correction was assessed for the group as a whole and then individually for the allograft and autograft groups. Furthermore, the graft sizes in those patients that lost correction were assessed. True loss of correction was at times difficult to assess given variability in foot positioning for the radiographs. Therefore, only those patients that lost 50% correction or greater were included with the nonunions as a failure of the LCL procedure.

Binary categorical variables were analyzed using Fisher's exact test. The nonparametric Wilcoxon ranksum test was used to examine continuous variables due to the small sample size in some groups. All analyses were performed using SAS software version 9.1 (SAS Institute, Cary, NC).

Results

Overall, there were a total of 20 failures; 13 patients had nonunions and seven patients lost 50% or greater correction, but there was no difference in failure between the auto- and allograft groups. (Figs. 1a–d), ($p=0.63$, 0.56 , and 1.00 , respectively) (Table 3). Of the 20 failures, 13 patients had allograft and seven had autograft. Nine allograft patients had nonunion, and four patients with allograft lost 50% or greater correction. Four autograft patients had nonunion, and three patients with autograft lost 50% or greater correction. None of the differences between allograft and autograft with respect to failure, nonunion, and loss of correction were statistically significant.

Fig. 1. **a** Initial postoperative AP radiograph of the foot obtained 2 weeks after surgery. **b** Initial post-operative lateral radiograph of the foot obtained 2 weeks after surgery. **c** AP radiograph obtained approximately 3 months later. Note LCL nonunion with hardware failure. **d** Lateral radiograph obtained approximately 3 months later. Note LCL nonunion with hardware failure

Table 3 Data summary

	Number	Percentage	Autograft	Allograft	<i>p</i> values
Failure	20	15.9% (20/126)	7	13	0.63
Nonunion	13	10.3% (13/126)	4	9	0.56
Loss of correction	7	5.6% (7/126)	3	4	1.00

The median time to clinical union was not significantly different between autograft (9.5 weeks) and allograft (10 weeks) ($p=0.13$). The median time to clinical union in the patients that healed was 10 weeks. The median time to radiographic healing in all patients was 19.1 weeks. The median time to radiographic healing in the autograft patients was 17.3 weeks, while the median time to radiographic healing in the allograft patients was 21 weeks. This difference was statistically significant ($p=0.01$).

The use of BMA did not appear to enhance allograft union ($p=0.52$), but the size of the graft did ($p=0.04$). Of the patients with allograft, nine of those with failure had the allograft bone mixed with BMA (9/45, 20.0%), while four did not (4/30, 13.3%). The average graft size in all patients was 7.40 mm. The graft size was significantly larger in those patients with failure (7.28 versus 8.05 mm).

Twenty-five patients of the 113 that healed lost radiographic correction (25/113, or 22.1%). The number of patients that lost correction was not significantly different between allograft (12/66, or 18.2%) and autograft (13/47, or 27.7%) ($p=0.26$). The average graft size of the 25 patients that lost some degree of correction was 7.80 mm compared to 7.15 mm in the 88 patients that did not. This difference was statistically significant ($p=0.02$).

Discussion

The results of the current study were unable to demonstrate a significant difference in healing rates between iliac crest allograft and autograft when used in LCL. Our data did not show any significant advantage to mixing the allograft with BMA. Time to radiographic healing was quicker in patients receiving autograft. Larger grafts did appear to predispose the osteotomy to nonunion and loss of correction.

This study has several limitations apart from its retrospective and nonrandomized design. First, the patients were treated by five different surgeons. However, each used the same surgical indications and similar technique. Two significant yet inherent weaknesses in this study were that the fixation used and the number of procedures varied between the patients. Fixation was entirely surgeon dependent, although the individual surgeons were consistent in terms of the hardware they used. Flatfoot correction incorporates a wide range of potential surgeries to address deformity. Although there was variation amongst the surgeons, almost all patients had a medializing calcaneal osteotomy, flexor digitorum longus (FDL) transfer, PTT debridement, either

gastroc recession or tendo-Achilles lengthening (TAL), and a medial procedure to bring the first ray down (i.e., cotton osteotomy or first TMT fusion). Other procedures were performed, but they were primarily to address secondary pathology, such as hammer toes. Also, the patients who had allograft were not uniform as some had BMA added. Although the inclusion of BMA perhaps makes conclusions more difficult to draw, the authors wanted to include adjuncts used specifically to aid healing. Moreover, there is a selection bias for these patients in that only relatively healthier patients are generally chosen to undergo flatfoot reconstruction due to the considerable recovery and risks associated with the surgery.

Another significant limitation is the outcome measures that we used. Time to radiographic and clinical union is difficult to rigorously define for several reasons. Clinical union is ultimately based on the individual surgeon's subjective assessment of the patient, especially given our retrospective format. Moreover, radiographic evaluation of the healing LCL graft is quite difficult. This difficulty stems from the fact that visualization of the anterior calcaneus is not always consistent, the hardware often obscures the bony interfaces, and the interface between the graft and calcaneus can remain apparent even when there appears to be bony bridging. It is unclear to what extent bony bridging must be present to consider the graft "healed" [13]. Furthermore, routine radiographs were generally only obtained at standard times postoperatively.

Two studies have previously compared allograft and autograft in LCL. Dolan et al. performed a prospective, randomized study comparing allograft and autograft in patients with AAFFD. Their study included 33 feet in 31 patients, with 18 randomized to allograft and 15 randomized to autograft. Though more patients in the allograft group healed by 8 weeks (94.4%) compared to autograft (60%), all patients in both groups were healed by 12 weeks. The primary endpoint was radiographic healing as demonstrated by "cortical or trabecular bridging across both sides of the graft in the absence of graft collapse and clinical evidence of healing." They noted no delayed union, nonunion, or hardware failure. Allograft patients had no complications; two autograft patients continued to have hip donor site pain at 3 months [10]. Grier et al. reported on healing of 51 feet in 49 patients who received either allograft with PRP or autograft for either Evans LCL or a calcaneocuboid distraction arthrodesis (CCDA) [16]. They had eight total nonunions, six of which had received autograft. Seven of the nonunions were with CCDA. A host

of studies have reported that calcaneocuboid distraction arthrodesis has a greater risk of nonunion than Evans lateral column lengthening [6, 7, 22, 23], perhaps explaining the findings in their study. However, the strikingly high rate of nonunions amongst their autografts remains difficult to explain.

The rate of nonunion in the current study is higher than the above two studies assessing lateral column healing in flatfoot correction. This may stem, in part, from differences in the definition of “radiographic union.” Dolan et al. found that 17 of 18 patients with allograft showed radiographic evidence of healing at 8 weeks compared to only one of 66 patients at the same time point in the current study. These authors did include clinical information in defining radiographic healing [10]. Grier et al. defined nonunion both clinically with pain and lateral swelling and radiographically with lucency at the graft–host interface or broken hardware [16]. In clinical practice, all evidence is taken into account to decide on the ultimately subjective “healed.” The majority of our patients with allograft were bearing full weight by approximately 9 weeks, although they may not have been fully radiographically healed.

The average time to radiographic healing was approximately 20 weeks. The difficulty in assessing radiographic union may have contributed to this long time. Many of the patients who were not considered radiographically healed for greater than 3 months were clinically doing well and bearing full weight. The average time to radiographic healing in Dolan's study was 8.9 weeks. Grier et al. do not present time to healing. In the current study, only five of 113 patients that healed were radiographically healed by 8 weeks.

Although larger grafts led to significantly decreased union, it is questionable whether this finding is clinically significant as the difference between these graft sizes was less than a millimeter (0.77 mm). The grafts used in both groups in the current study were smaller than those commonly reported in the literature in both clinical and biomechanical studies that generally report the use of a wedge of 10 mm or more [2, 3, 5, 7, 11, 14, 17, 19–21]. Perhaps larger grafts take longer to heal completely given the process of creeping substitution [4].

It is interesting to note that patients with autograft did heal more quickly from a radiographic standpoint. This fact does provide some evidence in favor of autograft versus allograft for this procedure. Although the difference in failure rate was not significant, there were more failures in the allograft group in total. There could be a difference that this retrospective study based on available patients was underpowered to identify.

In conclusion, the rate of nonunion of LCL was higher in our study than has generally been reported in the literature. There was no statistically significant difference in the failure rate amongst patients who received allograft versus those who received autograft. BMA did not appear to protect against nonunion. Larger grafts may be more susceptible to nonunion and loss of correction.

Disclosures Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a significant conflict of interest in connection with the submitted article. One or more of the authors have or will receive monies from a commercial entity that may be perceived as a potential conflict of interest.

Each author certifies that his or her institution has approved the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.

References

- Ahlmann E, Patzakis M, Roidis N, Shepherd L, Holtom, P. Comparison of anterior and posterior iliac crest bone grafts in terms of harvest-site morbidity and functional outcomes. *J Bone Joint Surg Am.* 2002;84-A:716–720.
- Arangio GA, Chopra V, Voloshin A, Salathe EP. A biomechanical analysis of the effect of lateral column lengthening calcaneal osteotomy on the flat foot. *Clin Biomech (Bristol, Avon).* 2007;22:472–477.
- Benthien RA, Parks BG, Guyton GP, Schon LC. Lateral column calcaneal lengthening, flexor digitorum longus transfer, and opening wedge medial cuneiform osteotomy for flexible flatfoot: a biomechanical study. *Foot Ankle Int.* 2007;28:70–77.
- Burchardt H. The biology of bone graft repair. *Clin Orthop Relat Res.* 1983;174:28–42.
- Chi TD, Toolan BC, Sangeorzan BJ, Hansen ST Jr. The lateral column lengthening and medial column stabilization procedures. *Clin Orthop Relat Res.* 1999;365:81–90.
- Conti SF, Wong YS. Osteolysis of structural autograft after calcaneocuboid distraction arthrodesis for stage II posterior tibial tendon dysfunction. *Foot Ankle Int.* 2002;23:521–529.
- Danko AM, Allen B Jr, Pugh L, Stasikelis P. Early graft failure in lateral column lengthening. *J Pediatr Orthop.* 2004;24:716–720.
- Deland JT. Adult-acquired flatfoot deformity. *J Am Acad Orthop Surg.* 2008;16:399–406.
- Deland JT, Page A, Sung IH, O'Malley MJ, Inda D, Choung S. Posterior tibial tendon insufficiency results at different stages. *HSS J.* 2006;2:157–160.
- Dolan CM, Henning JA, Anderson JG, Bohay DR, Kornmesser MJ, Endres TJ. Randomized prospective study comparing tri-cortical iliac crest autograft to allograft in the lateral column lengthening component for operative correction of adult acquired flatfoot deformity. *Foot Ankle Int.* 2007;28:8–12.
- Dumontier TA, Falicov A, Mosca V, Sangeorzan B. Calcaneal lengthening: investigation of deformity correction in a cadaver flatfoot model. *Foot Ankle Int.* 2005;26:166–170.
- Ellis SJ, Yu JC, Johnson AH, Elliott A, O'Malley M, Deland J. Plantar pressures in patients with and without lateral foot pain after lateral column lengthening. *J Bone Joint Surg Am.* 2010;92:81–91.
- Ellis SJ, Yu JC, Williams BR, Lee C, Chiu Y, Deland JT. New radiographic parameter assessing forefoot abduction in the adult acquired flatfoot deformity. *Foot Ankle Int.* 2009;30: 1168–1176.
- Evans D. Calcaneo-valgus deformity. *J Bone Joint Surg Br.* 1975;57:270–278.
- Goulet JA, Senunas LE, DeSilva GL, Greenfield ML. Autogenous iliac crest bone graft. Complications and functional assessment. *Clin Orthop Relat Res.* 1997;339:76–81.
- Grier KM, Walling AK. The use of tricortical autograft versus allograft in lateral column lengthening for adult acquired flatfoot deformity: an analysis of union rates and complications. *Foot Ankle Int.* 2010;31:760–769.
- Hintermann B, Valderrabano V, Kundert HP. Lengthening of the lateral column and reconstruction of the medial soft tissue for treatment of acquired flatfoot deformity associated with

- insufficiency of the posterior tibial tendon. *Foot Ankle Int.* 1999;20:622–629.
18. Johnson, KA; Strom, DE: Tibialis posterior tendon dysfunction. *Clin Orthop Relat Res.* 1989;239:196–206.
 19. Mosca VS. Calcaneal lengthening for valgus deformity of the hindfoot. Results in children who had severe, symptomatic flatfoot and skewfoot. *J Bone Joint Surg Am.* 1995;77:500–512.
 20. Sands AK, Tansey JP. Lateral column lengthening. *Foot Ankle Clin.* 2007;12:301–8, vi-vii.
 21. Scott AT, Hendry TM, Iaquinto JM, Owen JR, Wayne JS, Adelaar RS. Plantar pressure analysis in cadaver feet after bony procedures commonly used in the treatment of stage II posterior tibial tendon insufficiency. *Foot Ankle Int.* 2007;28:1143–1153.
 22. Thomas RL, Wells BC, Garrison RL, Prada SA. Preliminary results comparing two methods of lateral column lengthening. *Foot Ankle Int.* 2001;22:107–119.
 23. Toolan BC, Sangeorzan BJ, Hansen ST Jr. Complex reconstruction for the treatment of dorsolateral peritalar subluxation of the foot. Early results after distraction arthrodesis of the calcaneocuboid joint in conjunction with stabilization of, and transfer of the flexor digitorum longus tendon to, the midfoot to treat acquired pes planovalgus in adults. *J Bone Joint Surg Am.* 1999;81:1545–1560.
 24. Vora AM, Tien TR, Parks BG, Schon LC. Correction of moderate and severe acquired flexible flatfoot with medializing calcaneal osteotomy and flexor digitorum longus transfer. *J Bone Joint Surg Am.* 2006;88:1726–1734.