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Radiographic Outcomes of Titanium Augment vs Bone Graft in Lateral Column Lengthening for Adult-Acquired Flatfoot Deformity

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Abstract

Background: Lateral column lengthening (LCL) is a surgical procedure used to manage forefoot abduction and, in theory, also increases the longitudinal arch by plantarflexion of the first ray through tensioning the peroneus longus for patients with stage IIB adult acquired flatfoot deformity (AAFD). This procedure utilizes an opening wedge osteotomy of the calcaneus, which is then filled with autograft, allograft, or a porous metal wedge. The primary aim of this study was to compare the radiographic outcomes of these different bone substitutes following LCL for stage IIB AAFD.
Methods: We conducted a retrospective review of all patients who underwent LCL from October 2008 until October 2018. Preoperative weightbearing radiographs, initial postoperative radiographs, and 1-year weightbearing radiographs were reviewed. The following radiographic measurements were recorded: incongruency angle, talonavicular coverage angle (TNCA), talar–first metatarsal angle (T-1MT), and calcaneal pitch.
Results: A total of 44 patients were included in our study. The mean age of the cohort was 54 (range, 18-74). The study cohort was divided into 2 groups. There were 17 (38.7%) patients who received a titanium metal wedge and 27 (61.5%) that received autograft or allograft. Patients that underwent LCL with the autograft/allograft group were significantly older (59 vs 47 years old, $P = .006$). Patients who underwent LCL with a titanium wedge had a significantly higher preoperative talonavicular angle (32 vs 27 degrees, $P = .013$). There were no significant differences in postoperative TNCA, incongruency angle, or calcaneal pitch at 6 months or 1 year.
Conclusion: At 6 months and 1 year, no radiographic differences were found between autograft/allograft bone substitutes vs titanium wedge in LCL.

Level of Evidence: Level III, retrospective cohort study.

Keywords: lateral column lengthening, flatfoot, deformity, deformity correction, adult acquired flatfoot deformity, titanium wedge

Introduction

Adult acquired flatfoot deformity (AAFD) is a common foot and ankle disorder that leads to progressive pain and disability. AAFD affects an estimated 5 million adults in the United States, prevalent in 3% of women >40 years old and 10% of geriatric patients.[3] AAFD is typically attributed to posterior tibial tendon dysfunction, but the condition comprises a broad spectrum of ligamentous and tendinous failures including tenosynovitis, tendinosis, tendon elongation, and tendon tearing.[2,3] Historically, the Johnson and Strom[14] classification system, which was amended by Myerson,[1,2,13,22] was used to

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Table 1. Myerson Modification of Johnson and Strom Classification of Adult Acquired Flatfoot Deformity.[1]

Stage	Description
I	Mild medial pain and swelling with no deformity, can perform heel-rise test but demonstrates weakness on repetition, tenosynovitis on pathology with normal tendon length
II	Moderate pain with or without lateral pain, flexible deformity, unable to perform heel-rise test, elongated tendon with longitudinal tears
IIA	<30% talar head uncoverage
IIB	>30% talar head uncoverage
III	Severe pain, fixed deformity, unable to perform heel-rise test, visible tears on pathology
IV	Lateral talar tilt
IVA	Flexible ankle valgus without severe arthritis
IVB	Fixed ankle valgus with or without arthritis

categorize stages of AAFD by deformity and progression of tendinous and ligamentous dysfunction (Table 1). Recent literature has demonstrated that this disease progression is nonlinear and affects multiple areas of the foot and ankle with or without the involvement of posterior tibial tendon rupture. A more comprehensive classification system has been proposed by Myerson et al[17,18,23] based on the presence or absence of 5 independent deformities; hindfoot valgus, midfoot abduction, forefoot varus/medial column instability, peritalar subluxation/dislocation, and ankle instability (valgus tilting).

Surgical management of Johnson and Strom's[3,13,14] type IIB AAFD varies among surgeons. Lateral column lengthening (LCL) osteotomy, described initially by Evans in 1975,[9,20,25] is the standard joint-sparing surgical option for correcting the forefoot abduction. The osteotomy site is traditionally filled with iliac crest autograft or allograft.[7,10,27] Autografts come with the disadvantage of donor site morbidity, loss of correction due to graft resorption, and increased operative time required for grafting, while allografts can lead to the risk of disease transmission from the donor, decreased structural integrity, and higher nonunion rates.[7,10,16,27] Recent research has focused on alternative graft options to mitigate these risks leading to the introduction of porous titanium wedges.[12,19,21,24]

Porous metal implant's unique characteristics offer improved fixation by allowing for biologic ingrowth through the porous metal matrix, and these consequently increase their popularity in orthopaedic reconstructive procedures.[24] In 2010, Tucker[26] described the first use of porous titanium wedges in LCL as an alternative to traditional bone grafting. Results of clinical studies are promising and demonstrate low rates of radiographic nonunion, improved deformity correction, and increased pain relief.[12,19,21] One study of 28 LCL operations with porous titanium wedges showed all but 1 patient progressing to bony incorporation.[11] Recent studies showed this deformity correction was maintained over an average of 43.5 months without nonunion, wedge migration, or wedge removal.[19] Although initial studies have been encouraging, controversy still exists supporting the use of either iliac crest autograft and allograft or a titanium wedge implant for type IIB AAFD. Further, the literature has yet to directly compare the radiographic outcomes of the different treatment modalities in LCL for AAFD.

The aim of this study was to determine radiographic outcomes following LCL with a titanium wedge vs autograft or allograft. We hypothesized that titanium wedge implants would achieve comparable radiographic outcomes and improved clinical results vs patients who underwent the current gold standard of LCL with autograft or allograft of the iliac crest.

Materials and Methods

We conducted an institutional review board–approved retrospective medical record review to select patients meeting the following criteria: (1) over 18 years of age with at least stage II AAFD, (2) history of flatfoot reconstruction with LCL by one of 3 surgeons in a single practice between October 2008 until October 2018, (3) all causes of AAFD, (4) history of other concomitant accessory procedures including medializing calcaneal osteotomy, excision of accessory navicular, and flexor digitorum longus transfer, among others. Patients with neuropathic, inflammatory, or congenital disease were excluded from the study. Three orthopaedic surgeons fellowship trained in foot and ankle surgery performed all reconstructions. Data collected included demographic information, anterior-posterior and lateral radiographs of the foot, complications, and osseous union. To determine osseous union, we mirror Vosseller et al's[27] primary endpoint as defined by 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." The type of lateral column augment used as well as ancillary procedures was recorded based on operative notes. Choice of titanium wedge vs iliac crest bone graft was based on surgeon preference, with 1 surgeon preferentially using a titanium wedge, and the other 2 surgeons preferentially using bone graft. The procedures for both groups as well as follow-up for both groups occurred in parallel for this reason. The decision to use iliac crest allograft vs autograft was product of a patient-centric shared decision-making process.

The osteotomy is performed through a 4-cm lateral incision over the anterior calcaneal body. The extensor digitorum brevis muscle and peroneal tendons are retracted. The osteotomy is performed with a saw approximately 1.3 cm posterior to the calcaneocuboid joint. Care is taken to ensure that the medial cortex of the calcaneus is not violated. A small distractor is then used to expose the osteotomy and

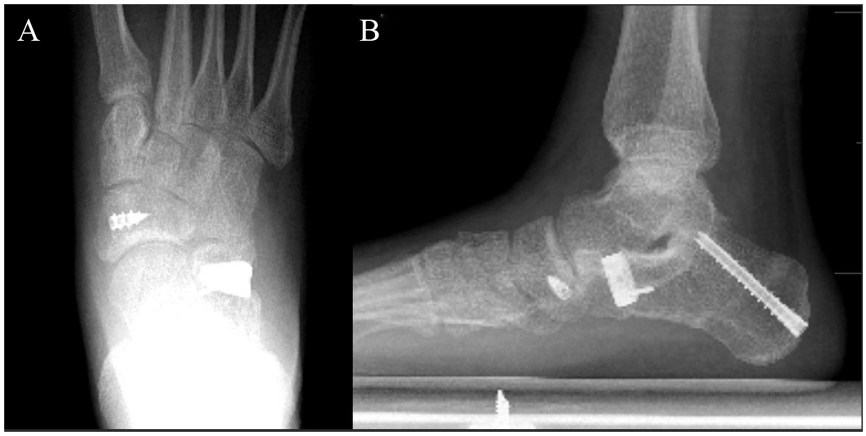

Figure 1. (A) Anterior-posterior and (B) lateral postoperative weightbearing radiographs following lateral column lengthening using porous titanium wedge augment.

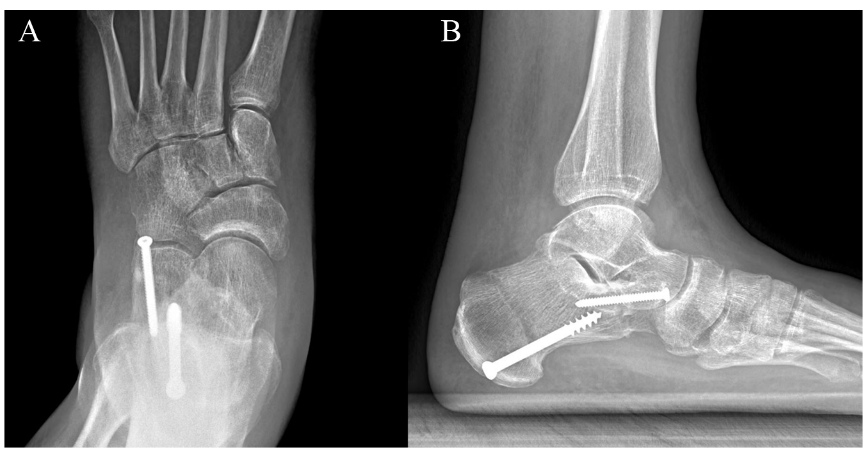

Figure 2. (A) Anterior-posterior and (B) lateral postoperative weightbearing radiographs following lateral column lengthening using bone graft.

trial wedges are used to determine the appropriate amount of lengthening. If iliac crest autograft is to be used, it is harvested via an incision directly over the anterior iliac crest. If a titanium wedge or allograft is used, and it is then placed into the osteotomy. A 2.4-mm locking screw can be placed through the titanium wedge. If there is further concern about stability of the wedge, a nitinol staple is at times applied over the lateral aspect of the osteotomy as well. A 3.5 mm cortical screw is typically used to secure allograft and autograft and is placed across the wedge beginning at the anterior calcaneal process.

Radiographic Evaluation

Patients who had adequate weightbearing anterior/posterior and lateral radiographs, as determined by the principal investigator, and follow-up weightbearing x-rays at least 1 year postoperatively were included. Patients were divided into 2 groups. In Group 1, a titanium Arthrex BioSync wedge (Arthrex, Naples, FL) was used for augmentation of the lateral column (Figure 1). In Group 2, iliac crest allograft or autograft was used (Figure 2). Measurements were performed by a single orthopaedist using preoperative weightbearing radiographs, the first postoperative weightbearing

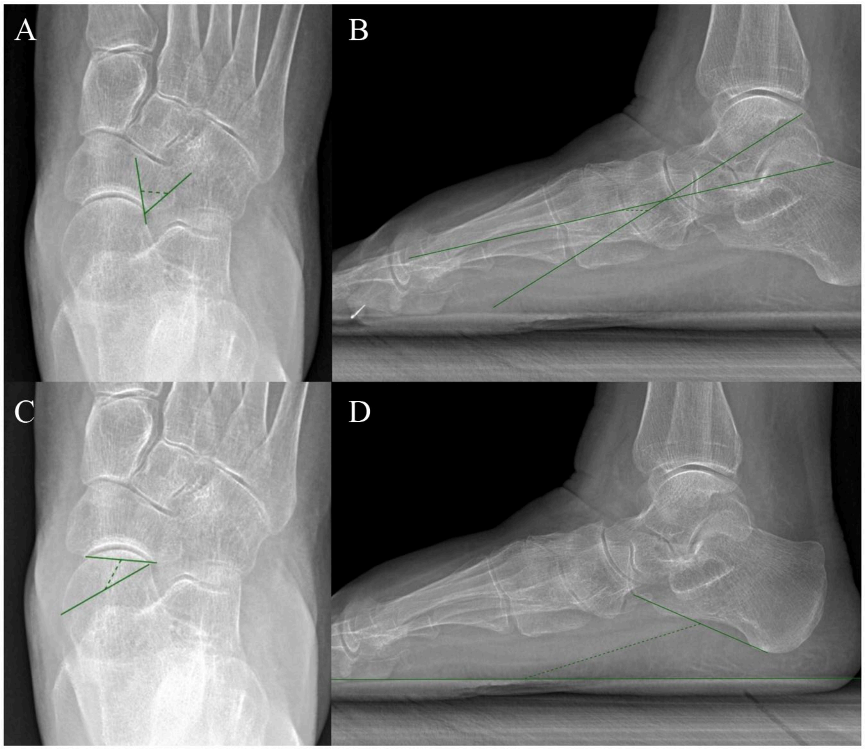

Figure 3. Measured radiographic parameters: (A) incongruency angle, (B) talar–first metatarsal angle (T-1MT), (C) talonavicular coverage angle (TNCA), and (D) calcaneal pitch.

radiographs, and 1-year postoperative weightbearing radiographs to assess for loss of correction. The anteroposterior radiographs were taken in a standardized fashion in which patients stood with their weight equally distributed between both feet, the feet shoulder width apart, and the arch relaxed. For each patient incongruency angle, talonavicular coverage angle (TNCA), talar–first metatarsal (T-1MT) angle, and calcaneal pitch were measured to assess midfoot alignment (Figure 3). Abduction was defined as incongruency angle greater than 5 degrees, a TNCA greater than 8 degrees, a T-1MT angle greater than 8 degrees, and a calcaneal pitch less than 19 degrees based on previously reported measurements.[4,6,8,15]

Statistical Analysis

Patient data were deidentified before analysis was conducted. Radiographic outcomes were analyzed by comparing the average measurements at final follow-up between patients treated with autograft or allograft and those treated with the titanium wedge for LCL. The difference in average radiographic parameters between patients who underwent LCL with bone graft vs titanium wedge was compared with a *t* test. Postoperative correction and maintenance of correction at the 1-year mark were compared with a *t* test. Complications were compared using a 2-sample independent *t* test for proportions. Statistical significance was defined at 5% ($P \leq .05$).

Results

A total of 44 patients were included in our study. The mean age of the cohort was 54 (range, 18-74). The study cohort was divided into 2 groups. There were 17 (38.7%) patients that received a titanium wedge and 27 (61.4%) that received iliac crest allograft or autograft. Of this group, 23 (52.3%) received iliac crest allograft and 4 (9.1%) received iliac crest autograft. Descriptive characteristics are depicted in Table 2. Patients who underwent LCL with the autograft/allograft group (58.6 years old) were significantly older compared to the titanium wedge group (47.2 years old) ($P = .006$). The sample of patients who were treated with the titanium wedge included significantly more females (77.8%) than the autograft/allograft group (73.3%) ($P = .009$).

Table 2. Patient Characteristics Among Patients Undergoing LCL With a Titanium Wedge or Autograft/Allograft.

Demographics	Titanium Wedge	Autograft/Allograft	*P* Value[a]
Total, n	17	27	—
Age, y, mean	47.2	58.6	**.006**
BMI, mead	32.1	31.7	.88
Female gender, %	77.8	73.3	**.009**

Abbreviation: LCL, lateral column lengthening.
[a]Boldface indicates significance ($P < .05$).

Table 3. Preoperative, Postoperative, and 1-Year Radiographic Measurement Comparison.

Radiographic Measurements	Titanium Wedge	Autograft/Allograft	*P* Value[a]
TNCA angle			
Preoperative	32.3	26.8	**.013**
Postoperative	8.8	6.9	.29
1-year follow-up	10.5	8.9	.29
T-1MT angle			
Preoperative	23.1	18.6	.068
Postoperative	6.4	5.3	.38
1-year follow-up	7.3	7.7	.78
Incongruency angle			
Preoperative	63.3	69.1	.70
Postoperative	7.7	11.5	.24
1-year follow-up	8.1	15.1	.73
Calcaneus pitch			
Preoperative	14.8	12.9	.16
Postoperative	22.4	25.4	.79
1-year follow-up	23.2	22.1	.78

Abbreviations: TNCA, talonavicular coverage angle; T-1MT, talar–first metatarsal angle.
[a]Boldface indicates significance ($P < .05$).

All patients treated with titanium wedges had a mean preoperative TNCA of 32.3 degrees, incongruency angle of 63.3 degrees, and calcaneal pitch angle of 14.8 degrees compared to the autograft/allograft group, which had a mean preoperative TNCA of 26.8 degrees, incongruency angle of 69.1 degrees, and calcaneal pitch angle of 12.9 degrees. Patients who underwent LCL with a titanium wedge had a significantly higher preoperative TNCA ($P = .013$) (Table 3). There was significant improvement in all preoperative and postoperative radiographic measurements for both groups: (1) incongruency angle mean decrease of 23.55 ($P < .0001$; range, 18.35-28.74) in the titanium group and 19.89 ($P < .0001$; range, 16.12-23.65) in the autograft/allograft group, (2) TNCA mean decrease of 16.63 ($P < 0.0001$; range, 10.75-22.50) in the titanium group and 13.26 ($P < .0001$; range, 10.16-16.36) in the autograft/allograft group, (3) T-1MT angle mean decrease of 52.16 ($P < .0001$; range, 39.04-65.28) in the titanium group and 57.49 ($P < .0001$; range, 49.50-65.47) in the autograft/allograft group, and (4) and calcaneal pitch mean increase of 11.31 ($P < .0001$; range, 5.904-16.71) in the titanium group and 12.47 ($P < 0.0001$; range, 9.696-15.26) in the autograft/allograft group. There were no significant differences in postoperative TNCA, incongruency angle, or calcaneal pitch postoperatively or at 1 year between the groups. A comparison between the amount of correction and change over the 1-year follow-up period showed no significant difference between the 2 groups (Table 4).

A comparison of the common complications in the 2 implant groups is depicted in Table 5. None of the patients who received the titanium wedge corrections led to nonunion followed up to 1 year postoperatively, in comparison to 3 of 27 (11.1%) reports of nonunion requiring correction in the autograft/allograft group. Clinically the most common complaint was for hardware irritation resulting in removal of hardware in 2 of 15 (13.3%) for the titanium wedge group, and 17 of 27 (63.0%) in the autograft/allograft group.

Discussion

This study hypothesized that porous titanium metal implants would have similarly efficacious radiographic corrections as compared to traditional practices for adult flatfoot deformity correction, with improved clinical results evaluated by radiographic parameters following LCL surgery. Until recently, this osteotomy has been filled with iliac crest autograft or allograft, which can lead to unfavorable short- and long-term complications. Harvesting the autografts can lead to significant donor site morbidity seen in 15% to 48% of cases,[24] persistent pain in 18% of patients at up to 1 year,[5] and longer operative time.[12] Although allografts do not carry the same risks and limitations, they are considered to be less osteogenic, associated with higher rates of nonunion, and carry the possibility of immunogenicity and disease transmission.[19,27] With the rising need for bone graft alternatives, along with advances in synthetic bone grafting technology, porous titanium metal implants have been turned to with the hope of decreasing risk of nonunion as well as donor site morbidity.[24,26]

Despite the promise of this technology, there are limited studies on its efficacy and safety among patients who received LCL. Gross et al[12] published a case series on postoperative imaging that showed the implants were effective in correcting significant deformities. In their 14-month postoperative follow-up, they also found improved scores and only a single case of nonunion. Building on these findings, Moore's team[21] conducted a retrospective analysis of 34 patients with stage IIB AFFD who were treated with porous titanium wedges in LCL, demonstrating significant postoperative radiographic correction in (1) the radiographic lateral

Table 4. Differences in Preoperative, Postoperative, and 1-Year Measures Radiographic Measures.

Radiographic Measurements	Titanium Wedge	Autograft/Allograft	*P* Value
TNCA preop. to postop. change	23.5	19.9	.18
TNCA postop. to 1-y change	–1.3	–1.7	.76
T-1MT preop. to postop. change	16.6	13.3	.28
T-1MT postop. to 1-y change	–1.1	–2.7	.13
Incongruency angle preop. to postop. change	52.2	57.5	.40
Incongruency angle postop. to 1-y change	1.5	–2.5	.31
Calcaneus pitch preop. to postop. change	–11.31	–12.5	.34
Calcaneus pitch postop. to 1-y change	4.3	3.2	.29

Abbreviations: postop., postoperation; preop., preoperation; TNCA, talonavicular coverage angle; T-1MT, talar–first metatarsal angle.

Table 5. Comparison in Frequency of Complication Rates Between the 2 Implant Groups.

Complication	Titanium Wedge, n/n (%)	Autograft/Allograft, n/n (%)	*P* Value
Nonunion	0/17 (0)	3/27 (11.1)	.16
Removal of hardware	2/17 (11.8)	17/27 (63.0)	**<.001**
Infection	1/17 (5.9)	1/27 (3.7)	.73
Pain	2/17 (11.8)	3/27 (11.1)	.94

Boldface indicates significance (alpha = 0.05).

T-1MT angle, (2) the percentage of talonavicular coverage, (3) the first metatarsocuneiform height, and the (4) hindfoot valgus angle. Importantly, this review presented no cases of nonunion, wedge migrations, or removal, suggesting good osteointegration of the implant.

With the growing body of evidence in support of the new implant, Matthews et al looked at longer-term follow-up in 2018. Based on a 4-year multicenter retrospective review, this group demonstrated that the radiographic corrections were maintained with no major complications or implant removal or migration.[19]

Expanding on this foundation, our study demonstrated that porous titanium wedge augments have similar clinical outcomes when directly compared with traditional bone grafting. For this, we compared the postoperative radiographic outcomes following LCL with a porous titanium wedge vs autograft or allograft. We found significant postoperative improvement in all radiographic measures following LCL with a porous titanium wedge vs autograft or allograft shown in the incongruency angle, TNCA, T-1MT angle, and calcaneal pitch, which were maintained at the 1-year follow-up. We did not find any significant difference between the 2 groups' radiographic outcomes.

Additionally, there were no reports of nonunion or loss of correction for the porous titanium group. Although 26% of the patients in the titanium group reported minor and major complications at up to 1-year follow-up, only 11.8% required hardware removal compared to the autograft/allograft group (11.1% and 63.0% rates of nonunion and hardware removal, respectively). The high rate of removal of hardware in the autograft/allograft group is attributed to the anterior calcaneal process screw used to maintain the LCL in this group, which is notably absent in the titanium wedge group. Hardware irritation at the calcaneocuboid joint with concomitant calcaneocuboid exostosis accounted for all instances of hardware removal. Although this is not a longitudinal study, these results suggest that porous titanium is an efficacious and clinically comparable alternative to the standard bone graft for LCL in patients with type IIB AAFD.

It is worth noting that our findings were limited by the shortcomings of retrospective chart reviews, as this analysis is reliant on the available records—meaning potential confounding factors could be absent from our data set. The lack of significant findings in our study could also be related to our limited cohort sizes. We grouped both iliac crest allograft and autograft into a single cohort because of the small number of patients who received autograft. We attribute the rate of autograft use to the shared decision-making process and patient aversion to the comorbidities associated with iliac crest autograft harvest, another obvious weakness of conducting this manner of retrospective study. Larger, multicenter studies are needed to determine whether there is a significant difference in the populations. Moreover, this study focused exclusively on objective radiographic findings and surgery-related complications, but it lacked subjective patient-centered outcomes. Filling in this gap would help to further elucidate an important aspect of postoperative surgical outcome measures in the comparison of titanium wedge augments vs bone graft.

Although larger, multicenter studies are needed to validate and expand on these early results, our findings suggest that titanium metal wedges are both safe and effective for continued use in LCL.

Conclusion

Successfully managing AAFD requires complex decision making to addresses each aspect of the deformity. LCL is a common surgical procedure used to treat forefoot abduction that occurs with stage IIB AAFD and is a constituent component of the principal treatment algorithm. Optimizing this aspect of surgical management will lead to improved outcomes overall. In both cohorts, we demonstrate radiographically stable osseous structure at 6 months and 1 year when compared to the standard autograft/allograft bone substitutes, suggesting titanium wedge augments are noninferior to bone graft in the short postoperative period, and thus may be a suitable substitute to avoid associated morbidity of autograft site. Future research should examine long-term patient-reported outcomes, rates of nonunion or osteointegration, and cost-effectiveness between bone graft vs titanium wedge augmentation.

Ethical Approval

This study was reviewed and approved by the Albany Medical Center IRB.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Andrew Rosenbaum, MD, reports consulting fees; payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events; and support for attending meetings and/or travel from Arthrex, Inc. ICMJE forms for all authors are available online.

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