Harvest of Calcaneal Bone Graft: Does Experience Matter?

KENT STATE UNIVERSITY | College of Podiatric Medicine

Natasha Bhagat B.S.[1] , Brandon Rogers B.S.[2], Deana Lewis B.S.[3]

1. Third Year Medical Student, Kent State University College of Podiatric Medicine, Independence, OH 2. Fourth Year Medical Student, Kent State University College of Podiatric Medicine, Independence, OH 3. Second Year Medical Student, Kent State University College of Podiatric Medicine, Independence, OH

Statement of Purpose

The purpose of this study is to examine whether experience in the podiatric field is necessary to obtain a precise amount of bone graft utilizing a modified technique for percutaneous harvest of cancellous calcaneal autograft.

Introduction and Literature Review

Bone grafts are commonly used in orthopedic surgery to augment arthrodesis and non-union revision, enhance fracture healing, and treat skeletal deficits [1,2,3]. The foot and ankle are locations that not only benefit from bone grafts, but can also carry the role of a bone graft harvest site. Bone grafts are characterized as autograft or allograft based on the source. Bone autografts have historically been the gold standard by providing properties of osteoconduction, osteoinduction and osteogenesis [4]. Furthermore, autografts do not possess a risk of disease transmission, unlike allografts [5]. Although allografts are readily available and provide an exact volume for larger osseous defects, they do not provide all three properties for proper osteosynthesis and can burden extra expenses; thus making autogenous bone graft to be superior in its ability to enhance bone healing [2]. Autograft bone is osteoconductive in that it provides a scaffold for osseous and fibrovascular ingrowth and proliferation. It is also osteoinductive in nature as it promotes growth factors and matrix proteins, which help modulate cellular processes essential to bone growth. Additionally, bone autograft is osteogenic as it provides osteoblasts, osteocytes, and precursors that can actively form bone [6,7].

Possible locations within the lower extremity that autografts can be harvested from are the iliac crest, distal and proximal tibial metaphysis, fibula, and the calcaneus. These sites are not equal when looking at complication rates or osteogenic potential [5]. Although the iliac crest has historically been chosen as the main autograft source, there are complications with iliac crest graft harvesting, like persistent donor site pain [3] that can be accompanied with a hematoma, wound infection, incisional pain, nerve injury, and/or stress fracture. Early complication rates were reported to be as high as 20-39% for minor and 2.5-10% for major complications [5]. Another common location at the proximal tibia has had documented complications such as iatrogenic fracture and hematoma formation [3,7]. For this reason and the limited scope of practice for foot and ankle surgeons, alternative harvest sites in the lower extremity have frequently been utilized [8].

As mentioned above, donor sites can have varying osteogenic potential. The iliac crest has a significantly higher content of active hematopoietic marrow when compared to the proximal and distal tibia and the calcaneus; however, smaller foot and ankle reconstructions usually do not require as potent autografts for a successful repair. Cancellous autograft is the most frequently used autograft in the foot and ankle due to its high surface area, presence of osteogenic cells, and rapid revascularization and incorporation [5]. It is typically used in areas that do not require significant structural support, such as filling small defects or applying it to prepared joint surfaces to aid in joint fusion. Some advantages of cancellous calcaneal graft harvest are that it requires a minimal incision and has low morbidity with minimal cost [9]. The calcaneus serves as a convenient harvest site from which autograft can be obtained with documented success and low complications rates [2,10]. Additionally, the calcaneus' relatively thin soft tissue envelope at its posterolateral aspect makes dissection easier in comparison to more proximal sites.

The adjunct use of calcaneal autografts in forefoot arthrodesis has limited complications due to minimally invasive technique and the small amount of harvested bone. The complications and morbidity associated with calcaneal autograft harvest is not widely studied; however, theoretical disadvantages include the limited volume of available graft, the unknown quality of harvested bone, potential sural nerve injury and iatrogenic calcaneal fracture.

Biddinger et al in 1998 described a technique utilizing an 8mm round core biopsy that purchased both medial and lateral cortices [10]. Roukis in 2006 described a similar approach using a 8mm trephine, but without penetrating the medial cortex [6]. DiDomenico and Haro in 2006 described a technique using a 3.5mm drill to breach the lateral wall and a bone curette to harvest cancellous bone [11]. Their calcaneal autograft harvested about 3-5cc. In comparison, Salawu et. al reported an average compressed volume of graft harvested of 7cc from the proximal tibia and 5.5cc from the iliac crest [12]. While Miller et. al recorded an average volume of 20cc from the anterior iliac crest [5]. As seen each harvest site varies in quantity of graft due to technique and anatomic location. To our knowledge, bone graft harvest volumes from the calcaneus have not been thoroughly investigated. The current study aims to present a variation of the technique described by DiDomenico and Haro, quantify bone graft harvest volume, and compare harvest success based on surgical experience in the podiatric field. This modified percutaneous technique for harvesting calcaneal cancellous autograft requires no additional surgical equipment or power instrumentation, thereby increasing operating room efficiency and decreasing costs associated with allograft use.

Figure 1: Measurement of bone graft with 3cc syringe

Materials and Methods

To prove the reproducibility of this percutaneous technique for calcaneal autograft, a study with 18 cadaveric samples, specifically nine matched-pairs of fresh frozen human cadaveric below-knee limbs, was performed where bone graft volume was obtained by both surgeon with prior practice and students without experience. All donors were matched to sex (6 Female, 3 male), general medical comorbidities, and age range (62.4 years). Samples excluded had a history of previous foot and ankle surgery or systemic musculoskeletal disease (osteoporosis, inflammatory arthropathies, spondylopathies, etc.). Calcaneal autograft was obtained via the surgeon's modified technique. Bone graft was quantified by podiatric medical students utilizing a 3cc syringe and plunger to pack and measure (Figure 1). Volume of bone graft obtained by surgeon versus student was measured and recorded (Table 1). Complete data analysis was performed using a commercially available statistical program called G-power on a personal computer. Power analysis with a 1-tail t-test for independent variables was utilized to calculate the following: an a priori test to compute required sample size, sensitivity to compute required effect size, criterion to compute α or p-values, and a post-hoc test to compute achieved power with different sample sizes.

Surgical Technique

The instrumentation necessary for adequate harvest includes: straight bone curettes, curved mosquito hemostat, #10 blade, sterile cup (Figure 2). The incision should be made inferior to the sural nerve and peroneal tendons on the posterolateral aspect of the heel. The incision is placed at the bisection of imaginary lines drawn between the distal tip of the fibula and posterior/inferior calcaneus and the cranial and caudal borders of the lateral calcaneus (Figure 3). It is vital that the harvest site be located within the midsubstance of the posterior tubercle of the calcaneus to ensure that a maximum amount of volume can be obtained while avoiding the important weight bearing architecture of the anterior and posterior calcaneus.

Once the site is located, a small stab incision is made parallel to the sural nerve with a #10 blade (Figure 4). The incision is carried down to the lateral wall of the calcaneus. A curved mosquito hemostat may be used if blunt dissection is necessary. Next, a small straight bone curette is inserted into the lateral wall of the calcaneus. The curette is spun back and forth with the surgeon's fingers mimicking a "hand drilling" technique. Once the lateral wall is punctured the first curette is removed and a slightly larger curette is inserted and the process is repeated.

Figure 2: Instrumentation for percutaneous calcaneal bone graft harvest

Figure 3: Identification of graft harvest site

Figure 4: Incision with #10 blade parallel to the sural nerve.

Once a large enough curette is used (3-4mm), the surgeon or student can safely harvest cancellous bone graft in an efficient manner. Cancellous bone is then curetted utilizing an "ice cream scoop" technique, with care to not violate the medial calcaneal wall. Once cancellous bone is extirpated it is placed into a sterile container for later use at the fusion site (Figure 5).

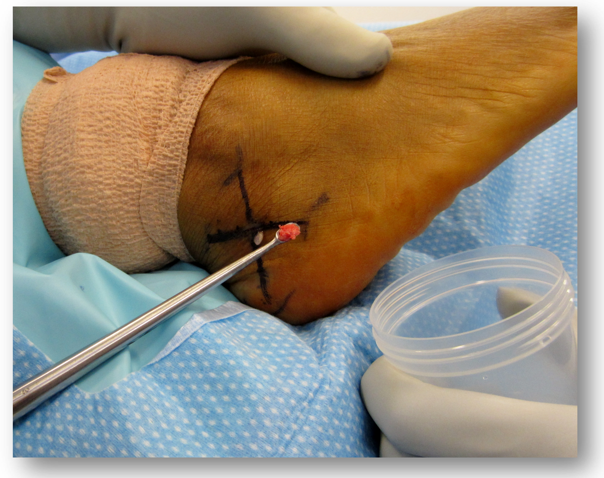

Figure 5: Bone graft is harvested and placed into a sterile container

Results

Sample	Age	Sex	Volume of Graft (Cubic Centimeters)	Surgeon or Student?
1	65	Male	0.7	Surgeon
2	65	Male	1	Student
3	54	Male	0.5	Surgeon
4	54	Male	0.8	Student
5	63	Female	0.8	Surgeon
6	63	Female	0.8	Student
7	70	Male	1.6	Surgeon
8	70	Male	0.4	Student
9	59	Female	0.9	Surgeon
10	59	Female	0.8	Student
11	63	Female	1.2	Surgeon
12	63	Female	0.7	Student
13	60	Female	0.5	Surgeon
14	60	Female	0.7	Student
15	66	Female	1.1	Surgeon
16	66	Female	0.7	Student
17	62	Female	1.3	Surgeon
18	62	Female	0.9	Student
Mean	62.44		0.86	

Table 1: Raw Data from 18 cadaveric limbs. Graft volumes listed for surgeon versus student.

Specimen	Volume of graft (cc) by surgeon	Volume of graft (cc) by student
1	0.7	1
2	0.5	0.8
3	0.8	0.8
4	1.6	0.4
5	0.9	0.8
6	1.2	0.7
7	0.5	0.7
8	1.1	0.7
9	1.3	0.9
Mean	0.96	0.76
Standard deviation	0.375	0.167

Table 2: Comparative volumes of bone graft obtained by surgeon versus student from 9-matched pairs of cadaveric specimens. Mean and standard deviation values for surgeon versus student listed.

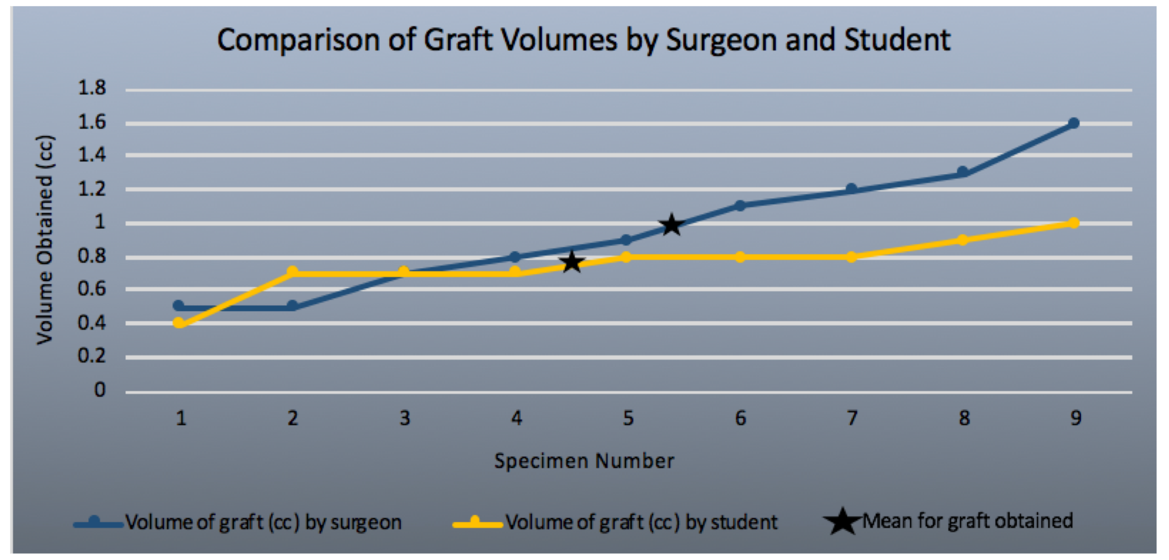

Figure 6: Graph displaying graft volumes by surgeon and student

A priori: Compute required sample size	
Input	
Tail	1
Effect size d	0.69
α err prob	0.05
Power (1-β err prob)	0.95
Allocation ratio N2/N1	1
Output	
Noncentrality parameter δ	3.34
Critical t	1.66
Df	92
Sample size group 1	47
Sample size group 2	47
Total sample size	94
Actual power	0.95

Table 3: A priori test for computing required sample size

Sensitivity: Compute required effect size	
Input	
Tail	1
α err prob	0.05
Power (1-β err prob)	0.95
Sample size group 1	9
Sample size group 2	9
Output	
Noncentrality parameter δ	3.44
Critical t	1.75
Df	16
Effect size d	1.62

Table 4: Sensitivity for computing required effect size

Criterion: Compute required α	
Input	
Tail	1
Effect size d	0.69
Power (1-β err prob)	0.95
Sample size group 1	9
Sample size group 2	9
Output	
Noncentrality parameter δ	1.46
Critical t	-0.19
Df	16
α err prob	0.57

Table 5: Criterion for computing required α with sample size of 18 total

Criterion: Compute required α	
Input	
Tail	1
Effect size d	0.69
Power (1-β err prob)	0.95
Sample size group 1	47
Sample size group 2	47
Output	
Noncentrality parameter δ	3.34
Critical t	1.69
Df	92
α err prob	0.05

Table 6: Criterion for computing required α with desired sample size of 94

Post hoc: Compute achieved power	
Input	
Tail	1
Effect size d	0.69
α err prob	0.05
Sample size group 1	9
Sample size group 2	9
Output	
Noncentrality parameter δ	1.46
Critical t	1.75
Df	16
Power (1-β err prob)	0.40

Table 7: Post hoc test for computing achieved power with our current sample size of 18 total

Post hoc: Compute achieved power	
Input	
Tail	1
Effect size d	0.69
α err prob	0.05
Sample size group 1	47
Sample size group 2	47
Output	
Noncentrality parameter δ	3.34
Critical t	1.66
Df	92
Power (1-β err prob)	0.95

Table 8: Post hoc test for computing achieved power with desired sample size of 94

Discussion

This surgical technique for obtaining a cancellous calcaneal bone autograft for midfoot and forefoot arthrodesis procedures is an efficient and adequate method for not only foot and ankle surgeons with extensive surgical practice, but also residents and students with little to no surgical experience. As we have previously described, the bone graft harvest can be completed with little to no associated morbidity to the patient. This easy technique does not require intra-operative fluoroscopy to guide incision placement, which saves operative time and cost and limits radiation exposure to the surgeon, staff, and patient.

In this study, each surgeon and student had 9 samples, which totals to a sample size of 18. The mean volume obtained from the surgeon was 0.96cc, while the mean volume obtained from students was at a slightly lower value of 0.76cc. This means there was only a difference of 0.20cc of bone graft harvest between the two groups. The standard deviation for surgeon versus student samples was respectively 0.375 and 0.167. As seen in figure 6, the surgeon has a higher variance in values shown by the steeper slope and a higher average volume harvested; however, there is still an overlap between the obtained harvest volumes by both groups. This signifies that experience does not necessarily correlate with graft harvest volume based on our data.

Tables 3-8 display statistical results obtained by the G-power application to test the accuracy of our data. Utilizing an a priori test for computing required sample size, it showed that 76 more samples or 38 more cadavers would be necessary to show a statistical significance. A sample size of 47 samples per surgeon and student (total of 94 samples) would allow there to be more variance in volume of bone graft obtained. The critical t-score Calculating sensitivity with our data displaced a small effect size of 0.69, which concludes there was not a wide enough range of volumes obtained from surgeon versus student. Similar to increasing the sample size to a total of 94, a larger effect size of 1.62 allows for a wider range of harvest amounts between the two groups. With the criterion test, we were able to see that α or the p-value for a sample size of 18 is 0.57, while a sample size of 94 gives a statistically significant p-value of 0.05.The critical t value of a sample size of 18 is only -0.19, while the critical t value of a sample size of 94 is 1.69. Lastly, a post-hoc test to compute achieved power was completed. Our data had a lower power of 0.40 or 40%, meaning that there is a higher chance of false negatives to be present and less certainty that we can conclude that experience does not correlate with graft harvesting. A post-hoc test completed with the desired sample size of 94 would output a power of 0.95 or 95%; thus allowing more accurate results that could prove experience in the podiatric surgical field is necessary to perform a successful calcaneal autograft using this technique.

We determined the average graft volume to be 0.86cc overall. This is a lower volume obtained in comparison to harvest sites from the iliac crest, tibia, and the calcaneus with the graft technique by DiDomenico and Haro; however, we believe this volume to be ideal for primary 1st MPJ arthrodesis and Lapidus arthrodesis cases. This volume can also be useful for digital arthrodesis procedures, as well.

Harvesting of autogenous bone graft continues to be a reliable adjunctive procedure in many orthopedic surgical cases. Within the realm of the foot and ankle, the calcaneus has been identified as a viable source for autogenous bone graft [2,10,11]. Previously, the techniques for harvesting calcaneal bone graft required either an invasive method or the need for power instrumentation [6,11]. To our knowledge, this is the first report of the quantification of graft volume, as well as looking at the ease of harvesting a graft based on experience in the field.

The limitations of this study mainly concern the use of cadaveric specimens as a data source and the small sample size that made for a narrow variation in the volumes obtained. A study using a 94 samples would allow a more definite conclusion to be made. Along with this, the use of fresh-frozen cadavers could slightly alter the quality of bone available for harvest; thus skewing the volume results. In attempts to lessen this risk, limbs were thawed only once prior to graft harvesting. For more accurate results, a study on living patients would be essential.

Based on the ease of this technique with similar volumes obtained by surgeon with prior practice and students with no practice in the surgical field, this percutaneous harvest of cancellous calcaneal bone autograft is a procedure that can be completed by all foot and ankle surgeons even without practice. Our study proves that prior experience within the field and prior practice with this technique is not necessary to obtain a successful and safe bone graft harvest for forefoot and midfoot joint procedures.

References

1. DiDomenico LA, Thomas ZM. Osteobiologics in Foot and Ankle Surgery. *Clin Podiatr Med Surg.* 2015;32:1-19.
2. Raikin SM, Brislin K. Local bone graft harvested from the distal tibia or calcaneus for surgery of the foot and ankle. *Foot Ankle Int.* 2005;26:449-453.
3. Brawley SC, Simpson RB. Results of an alternative autogenous iliac crest bone graft harvest method. *Orthopedics.* 2006;29:342-346.
4. Arner JW, Santrock, RD. A historical review of common bone graft materials in foot and ankle surgery. *Foot & Ankle Specialist*. 2014;7(2):143-151.
5. Miller, Christopher, Chiodo, Christopher. Autologous Bone Graft in Foot and Ankle Surgery. *Foot and Ankle Clin. 2016;(21):825-837.*
6. Roukis T. A simple technique for harvesting autogenous bone grafts from the calcaneus. *Foot Ankle Int* 27: 998- 999, 2006.
7. Fitzgibbons TC, Hawks MA, McMullen ST, Inda D. Review article: bone grafting in surgery about the foot and ankle: indications and techniques. *J Am Acad Orthop Surg*. 2011;19:112-120.
8. Myeroff C, Archdeacon M. Autogenous bone graft: donor sites and techniques. *J Bone Joint Surg Am*. 2011;93(23):2227–2236.9.
9. Chou LB, Mann RA, Coughlin MJ, McPeake WT 3rd, Mizel MS. Stress fracture as a complication of autogenous bone graft harvest from the distal tibia. *Foot Ankle Int.* 2007;28:199-201.
10. Biddinger KR, Komenda GA, Schon LC, Myerson MS. A new modified technique for harvest of calcaneal bone grafts in surgery on the foot and ankle. *Foot Ankle Int*. 1998;19:322–26.
11. DiDomenico LA, Haro AA 3rd. Percutaneous harvest of calcaneal bone graft. *J Foot Ankle Surg.* 2006;45:131-3.
12. Salawa ON, Comparative Study of Proximal Tibia and Iliac Crest Bone Graft Donor Sites in Treatment of Orthopaedic Pathologies. *Malayasian Orthopaedic J. 2017;* 11(2):15-19.