Tricortical Bone Grafts for Treatment of Malaligned Tibias and Fibulas

Joseph Borrelli Jr. MD, Stéphane Leduc MD, FRCSC,
Ronald Gregush MD, William M. Ricci MD

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Abstract Malunions and malaligned nonunions of the tibia and fibula after fracture alter limb function and can be corrected only with surgical intervention. We sought to determine whether using tricortical portions of the iliac crest in conjunction with osteotomy and internal fixation could successfully treat malunions and malaligned nonunions of the tibia and fibula. Seventeen patients with either a malunion or a malaligned nonunion of the tibia or fibula were treated with an osteotomy, deformity correction, and placement of an autogenous iliac crest tricortical bone graft with open reduction and internal fixation (ORIF). The minimum followup was 3 months (average, 32 months; range, 3–118 months). Sixteen patients (94%)

had clinical and radiographic evidence of healing at an average of 99 days (range, 43–229 days). Major complications occurred in four patients; one had a persistent nonunion, two had wound infections, and one underwent resection of the distal fibula for subsequent development of fibulotalar arthrosis after ankle arthrodesis. Minor complications occurred in two patients, one tendinitis and one persistent malunion. There were no complications at the iliac crest bone graft site. Autogenous iliac crest tricortical bone grafts, when used in conjunction with correction of alignment and stable internal fixation, are a reasonable option for treatment of nonunions and malaligned nonunions of the tibia and fibula.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

J. Borrelli Jr. (✉)
Department of Orthopaedic Surgery, UT Southwestern Medical Center, 1801 Inwood Road, WA4.312, Dallas, TX 75390-8883, USA
e-mail: joseph.borrelli@utsouthwestern.edu

S. Leduc
Université de Montréal Hôpital Sacré-Coeur de Montréal, Montreal, QC, Canada

R. Gregush
Southern California Orthopaedic Institute, Van Nuys, CA, USA

W. M. Ricci
Department of Orthopaedic Surgery, Washington University School of Medicine, St Louis, MO, USA

Introduction

The development of tibial and fibular malunion and malaligned nonunion after fracture results in alterations in gait, lower extremity mechanics, functional impairment, and an unpleasant cosmetic appearance [6, 7, 15]. Deviation from normal alignment causes alterations in joint reaction forces and increases shear stress on the articular cartilage of neighboring joints, which could lead to degenerative arthritis [7, 15]. Surgical realignment presumably restores normal joint reaction forces and corrects the mechanical axis of the limb. Techniques used to correct long bone malunions and malaligned nonunions include oblique or closing or opening wedge osteotomy, dome osteotomy, corticotomy, distraction osteogenesis, and tricortical bone grafts [2, 5, 9, 11–14, 16–18].

Osteotomy and placement of a tricortical bone graft at the apex of the deformity allows immediate and accurate

alignment correction with a low complication rate. This technique is particularly useful for treatment of malunions and malaligned nonunions of the distal tibia and fibula, in which other techniques would be difficult or ineffective. The major disadvantages include the requirement for harvesting bone at a distant site and creating two separate healing surfaces at the site of deformity correction [1, 3, 4, 12, 13, 17, 18].

We describe our technique for treating malunions and malaligned nonunions of the distal diaphysis and metaphysis of the tibia and fibula using autogenous iliac crest tricortical bone grafts. The goals of this study were to (1) evaluate the ability of this technique to obtain and maintain correction of alignment of the tibia and fibula; and (2) identify the complications associated with this technique.

Materials and Methods

We retrospectively reviewed 17 patients, eight with malaligned nonunions and nine with malunions of the distal tibia or fibula, treated from May 1998 to October 2005.

Patients were treated using a technique that included an osteotomy, or takedown of the nonunion, autogenous iliac crest tricortical bone graft, and compression plate fixation. The senior surgeons (JB, WR) began using this protocol in May 1998 to treat selected malunions and malaligned nonunions of the lower extremity. To be included in the study, patients had to have a malunion or malaligned nonunion of the tibia or fibula (5° varus or greater, 10° valgus or greater), which either because of the location (extremely proximal or distal) or nature of the deformity (pure shortening), was judged uncorrectable with other means of deformity correction. Although these patients could have been potentially treated with distraction osteogenesis with the use of a circular external fixator, this technique was not in the armamentarium of the senior surgeons. There were 12 men and five women with an average age of 45 years (range, 29–64 years). Eleven patients had either a malaligned nonunion or malunion of the tibia and fibula: in four patients only the tibia had a malaligned nonunion or malunion, and of the remaining patients, one had a malunion of the fibula and one had a malaligned nonunion (Table 1). Of the two patients treated

Table 1. Patient characteristics

Patient number	Gender	Age (years)	Location	Mechanism of injury	Preoperative alignment	Deformity (degrees)	NU/MU	Tricortical graft height (mm)		Time to healing (months)	Complications
								Tibia	Fibula		
1	M	41	Distal tibia	Fall	Varus	27	NU	20		4	None
2	M	50	Distal tibia	Fall	Varus	9	NU	28	10	4	Abscess, I & D
3	F	43	Distal tibia	Fall	Varus	33	NU	25	24	6	None
4	F	64	Distal tibia	MVC	Valgus	25	NU	30		3	Achilles/peroneal tendinitis
5	F	59	Distal tibia	Fall	Varus	17	MU	15		3	None
6	M	34	Distal tibia	Fall	Varus	15	MU	20		5	Talofibular arthritis
7	M	36	Distal tibia	Crush	Valgus	12	MU	14	21	8	Pain at iliac crest (resolved)
8	F	43	Distal tibia	MVC	Varus	19	MU	22		3	None
9	M	55	Distal tibia	Fall	Varus	34	MU	25		6	Wound dehiscence
10	M	31	Distal tibia	Crush	Varus	14	MU	22		3	Malunion
11	M	53	Distal tibia	Fall	Varus	6	NU	22		3	None
12	M	31	Tibia/ fibula	Fall	Varus	18	NU	25		5	Nonunion
13	M	43	Fibula	Fall	Shortening	0	MU		20	4	None
14	M	29	Fibula	Iatrogenic	Shortening	0	NU		17	2	None
15	M	46	Distal tibia	Fall	Varus	30	MU	22		2	None
16	F	45	Distal tibia	MVC	Valgus	10	MU	14	10	2	None
17	M	64	Distal tibia	Fall	Varus	19	NU	45		3	None
Summary	M = 12 F = 5	Average, 45 range, 29–64	Tibia: 15 Fibula: 2			Average, 19 mm range, 0–34					

F = female; M = male; NU = nonunion; MU = malunion; MVC = motor vehicle crash; I & D = incision and drainage.

for fibular deformities, one had shortening after a fracture causing ankle pain (Patient 13) and the other had shortening and nonunion at the previous bone graft site (Patient 14). Four patients had a history of infection before the index procedure. Preoperatively each patient underwent a thorough history and physical examination and laboratory assessment, including C-reactive protein, erythrocyte sedimentation rate, and CBC. Based on the results of these investigations at the time of the index procedure, none of the patients had evidence of active infection. The original fractures were treated with casting, plating, or intramedullary nailing before development of the malunion or malaligned nonunion and requiring ORIF with iliac crest bone graft. Therefore, these 17 patients represented a consecutive series of patients treated with a tricortical iliac crest bone graft and ORIF for deformity correction. The minimum followup was 3 months (average, 32 months; range, 3–118 months). All patients were available for followup. Our study was approved by the Institutional Review Board.

We obtained preoperative AP and lateral plain radiographs of the malaligned and contralateral normal limbs for each patient. Angular deformity was determined in the sagittal and coronal planes to determine the plane of maximum deformity. We assessed the presence of a clinically relevant rotational deformity of the involved limb by physical examination and the findings were compared with those of the contralateral limb. Owing to the lack of considerable rotational deformity in any of the study patients, CT scans to further assess rotation were not obtained.

Each patient received prophylactic intravenous antibiotics (2 g Kefzol; Eli Lilly & Co, Indianapolis, IN) 30 minutes preoperatively and 1 g intravenously every 8 hours for 24 hours postoperatively. The deformity site generally was exposed through previous surgical incisions to reduce the risks of wound complications. We identified the deformity site and performed the osteotomy with an oscillating saw (Synthes, Paoli, PA), or the nonunion site was taken down to allow correction of the deformity. When necessary, the osteotomy generally was made parallel to the neighboring joint. In the case of a nonunion, the site was taken down by removing fibrous tissue, and the bone ends were freshened with a burr (MicroAire, Charlottesville, VA). We corrected limb malalignment by using a laminar spreader placed in the osteotomy or nonunion site opening the site until achieving overall alignment correction. Intraoperative biplanar radiographs were used to confirm the angular correction, the defect size was determined, and a slightly larger iliac crest tricortical bone graft was harvested after exposure of the ipsilateral iliac crest. We harvested the bone graft with an oscillating saw with irrigation to minimize overheating and bone necrosis. To maximize contact between the graft and the host bone and

Fig. 1 A photograph shows a tricortical iliac crest bone graft. The harvested graft was approximately 5 mm larger than the defect. The cortical bone was removed at the edges to leave the cancellous bone proud to facilitate healing.

to assure a snug fit between the graft and host bone, 1 to 2 mm of cortical bone was removed from both ends of the graft, leaving the cancellous bone proud (Fig. 1). The graft was placed in the defect and secured using flat-ended tamps. We used small fragment dynamic compression plates, one-third tubular and cloverleaf plates, and cortical screws (Synthes, Monument, CO) to stabilize the construct in compression. Additionally, morselized corticocancellous bone graft taken from the same iliac crest site was placed at the bone graft interfaces (Figs. 2, 3).

We used a standard protocol to minimize bleeding complications at the bone graft site. Once the bone graft was harvested, hemostasis of the surrounding soft tissues was obtained with electric cautery. FloSeal (Baxter International, Inc, Fremont, CA), a bovine collagen mixture designed to facilitate clot formation and minimize bone bleeding, was applied to the bone graft site and the area was packed with a lap sponge for 5 minutes. Once hemostasis was assured, a Hemovac (Zimmer, USA, Dover, OH) drain was placed and the incision was closed with Number 1 Vicryl suture (Ethicon, Inc, Somerville, NJ) for the deep fascia, 2-0 Vicryl (Ethicon, Inc) for the superficial fascia, and subcutaneous tissue and surgical staples for the skin. We closed the extremity site in layers generally with 2-0 Vicryl (Ethicon, Inc) and nylon (Ethicon, Inc) for the skin. Once the surgical incisions were closed, a sterile dressing and a well-padded plaster splint were applied to the limb.

Postoperatively, we maintained the limbs in a splint for approximately 10 days followed by suture removal and initiation of active-assisted range of motion of the neighboring joints. For the first 6 weeks, the patients were kept touch-toe weightbearing and then advanced to partial weightbearing (23 kg) before advancing to full weightbearing at 3 months postoperatively.

Fig. 2A–C (A) Anteroposterior, (B) mortise, and (C) lateral ankle radiographs show distal tibial nonunion and fixation failure after ORIF of an open high-energy tibial plafond fracture.

Fig. 3A–C (A) Anteroposterior, (B) mortise, and (C) lateral ankle radiographs are shown 10 months after correcting the alignment, placing a 4-cm tricortical iliac crest bone graft, and performing revision ORIF of the distal tibia and fibula.

Each patient was examined and had serial radiographs at regular intervals (2, 6, and 12 weeks, then approximately every 3 months) until healing was complete or until the diagnosis of a persistent nonunion was made. The determination that bone union had occurred was based on (1) history and physical examination with pain-free weightbearing without the use of assistive devices; and (2) return of functional use of the extremity. Radiographic union was considered to have occurred when bridging trabeculae were thought to be present across the osteotomy sites, there was no loosening of the implants or failure and this stability was maintained with time. The treating physicians relied on their clinical experience, the interim history taken from the patient, and the physical

examination. Occasionally, if there was any question regarding whether the osteotomy sites had healed, consultation with a dedicated musculoskeletal radiologist was sought. We defined radiographic healing as the presence of bridging trabeculae crossing the graft sites, and it was confirmed by stability of the fixation with time. Bone union was assessed by the treating physician (JB, WR) and confirmed with radiology staff. Acceptable tibia alignment was defined as alignment in the coronal plane less than 5° varus or less than 10° valgus and less than 15° procurvatum or recurvatum in the sagittal plane. Immediate postoperative radiographs and the most recent radiographs were used to determine the amount of correction and maintenance of alignment during healing.

Results

Sixteen patients (94%) had clinical and radiographic evidence of healing at the operative site at an average of 99 days (range, 43–229 days) postoperatively. One patient had a persistent nonunion (6%) (Table 1). The average total angular correction was 21° (range, 25° valgus to 34° varus). The two patients who underwent placement of a tricortical iliac crest bone graft for an isolated fibula nonunion were not included in this calculation nor was the one patient who underwent a tricortical graft to maintain length for an the ankle fusion. The amount of angular correction realized at the time of surgery was preserved with time in each patient. The average height of the tricortical graft was

23 mm (range, 14–45 mm) in the tibia and 16 mm (range, 10–24 mm) in the fibula.

One patient had failure of the nonunion treatment with this technique. This patient initially sustained an open pilon fracture in a motor vehicle collision. Originally, he underwent ORIF and subsequently had a nonunion of the tibial metaphysis develop (Fig. 4). Revision ORIF then was performed with placement of a tricortical bone graft. Unfortunately, the nonunion persisted and the patient underwent an ankle arthrodesis (Fig. 5). At the time of the second revision surgery, the previous tricortical graft was necrotic and had lost all of its structural integrity. The ankle arthrodesis was performed using a similar tricortical bone graft and the patient achieved healing uneventfully (Fig. 6).

Fig. 4A–C (A) Anteroposterior, (B) mortise, and (C) lateral ankle radiographs show a very distal tibial nonunion after ORIF of a tibial plafond fracture.

Fig. 5A–C (A) Anteroposterior, (B) mortise, and (C) lateral ankle radiographs are shown after bone grafting and revision ORIF. Persistent nonunion continued, causing fixation and implant failure.

Fig. 6A–C (A) Anteroposterior, (B) mortise, and (C) lateral ankle radiographs show the patient after correcting alignment with a second tricortical iliac crest bone graft and ankle arthrodesis with an anterior and medial plate.

Major complications at the operative site occurred in four patients; these included one patient with nonunion who underwent revision surgery, one patient who had a secondary flap for wound dehiscence, one patient who had irrigation and débridement and intravenous antibiotics for wound infection, and one who had removal of the distal fibula for the development of arthritis at the fibulotalar joint. The patient who experienced the wound dehiscence had a culture positive wound that responded positively to local wound care and flap coverage and achieved healing of his osteotomy and soft tissues uneventfully. Minor complications occurred in two patients, including Achilles and peroneal tendinitis and a persistent malunion not requiring surgery. No patients experienced major or minor complications at the iliac crest bone graft site. Only one patient had moderate discomfort at the graft site 3 months post-operatively and this resolved by the time of final followup.

Discussion

Correction of posttraumatic deformity of the lower extremity is desirable to restore function and appearance. We describe our technique for treating malunions and malaligned nonunions of the distal diaphysis and metaphysis of the tibia and fibula using autogenous iliac crest tricortical bone grafts. The goals of this study were to (1) evaluate the ability of this technique to obtain and maintain correction of alignment of the tibia and fibula; and (2) identify the complications associated with this technique.

There were several limitations to our study. First, plain radiographs are a suboptimal way to measure healing and it is difficult to determine the exact time when acute fractures or nonunions have united. The difficulty in these

cases exist as a result of several factors. For one, in each case, the bone graft was inserted in such a way as to be compressed between the proximal and distal fragments and since we fashioned the graft so that the cancellous bone extended beyond the cortical bone, the interface between the graft and the bone was not well seen. Second, many of these patients already had previous surgical changes in this area and with the addition of metallic implants it was difficult to thoroughly assess this area. Long-leg standing radiographs were not used in the care of these patients and, therefore, we are unable to determine whether the malunion correction was adequate to restore mechanical alignment of the limb [8, 10]. However, our goal was to describe the technique and the success and complications we experienced in the treatment of these difficult malunions and malaligned nonunions. No clinical assessment was performed to determine whether correction of the alignment improved overall outcome or function of these patients. Other limitations of our study include the nonrandomized design, although the patients reflect the typical heterogeneous trauma patient population and therefore this technique is applicable to similar patient populations. Another limitation was the lack of a treatment protocol regarding exact surgical technique, graft size, and implants used to stabilize the osteotomies. In general, these patients were treated similarly. Also, despite a busy trauma center, we identified only a small number of patients treated for this type of deformity, meaning there may be a limited need for this type of surgical correction in the general population.

Osteotomy of a malunion or taking down of a nonunion, deformity correction, and inserting a tricortical iliac crest bone wedge with internal fixation is a promising technique for treating lower extremity malunions and malaligned

nonunions not amenable to other procedures. This technique ultimately resulted in correction of deformity in 94% and 100% healing of the bone-grafted sites. Sixteen patients (94%) achieved healing after one surgery, and one patient achieved union after a second surgery.

Some authors have reported the use of osteotomies with or without insertion of a tricortical iliac crest bone graft for treating malunions and nonunions of the lower extremity and ankle osteoarthritis [4, 9, 11–14, 16–18]. In these reports, this technique was used for ankle fusions after failed total ankle arthroplasty, tibia-fibula malunions, and for bone block fusions of the foot and ankle. Good results have been obtained using a supramalleolar osteotomy with iliac bone graft under compression for realigning the distal tibia while maintaining an intact fibula [5]. Tricortical iliac crest grafts also have been used for ankle fusion in eight patients after removal of a total ankle arthroplasty [4]. The average size of the graft in this report was approximately 13 mm high. Six of the patients (85%) obtained union after the index procedure, but one patient (15%) had a persistent nonunion despite revision attempts. Tricortical bone graft also was used successfully for lengthening of malunited fibulas after ankle fractures [18]. A low tibial osteotomy with opening wedge osteotomy of the tibia and insertion of tricortical iliac crest bone grafts was used in 12 of 18 patients treated for primary ankle osteoarthritis [13]. Although all of these patients eventually achieved healing, a delayed union was noted in four. In an additional study, nine patients were treated with an opening wedge osteotomy for posttraumatic varus deformity of the ankle [12]. The average angular correction was 17°, and the average height of the iliac bone graft was 12 mm [12]. None of these patients reported chronic iliac crest pain and only one patient had a delayed union. Our results are consistent with published results and show grafts as much as 4 cm in height may be used successfully to correct malalignments of the tibia.

Complications at the surgical site were relatively few in our study. In posttraumatic situations, the distal tibia and fibula have a precarious soft tissue coverage that becomes even more precarious with repeated operations and internal fixation. The only deep infection was in a patient with insulin-dependent diabetes who initially was treated for an open pilon fracture and who previously was treated for osteomyelitis at that injury site. Two patients required a flap; one was planned and the other was secondary to wound dehiscence and soft tissue loss with exposure of the plate and bone.

The use of distraction osteogenesis was reported in 23 lower extremity deformities with good correction [16]. However, each case was associated with pin tract infections and a 36% major complication rate and an average of 158 days in the external fixator. Good correction, however,

was reported with single-cut oblique osteotomy in 15 patients with tibial diaphyseal malunions [11]. In that study, there were two failures, one for wound dehiscence and one for nonunion and plate failure. In our patients, an oblique osteotomy would not have been feasible because of the location of the deformity and as a result of several patients having residual bone defects. Although it is possible that some, if not all, of our patients could have been treated with osteotomy and distraction osteogenesis, the one-stage procedure described saved our patients from the discomfort of the external fixator and the sometimes high complication rate associated with that technique.

Studies have suggested improvement in the historically high complication rates at the iliac crest site after harvesting a bone graft. Major complications were reported in 8% (five of 66) of patients who underwent an anterior iliac crest bone graft and in 2% (one of 42) of patients who had a posterior iliac crest bone graft [1]. In a much larger study of 180 patients who underwent anterior iliac crest bone graft, 90% reported no pain at the bone graft site at latest followup, although 27% reported initially that pain at the graft site was greater than the pain at the operative site [3]. None of these patients had extra hospital days because of the bone graft harvest and there were no deep infections, although 7% of the patients had a postoperative hematoma or seroma. In our study, the second surgical site (the iliac crest bone graft site), which was managed with a thoughtful protocol, was not a source of continued discomfort or complications, except in one patient who reported discomfort at the site for 3 months.

Despite potential limitations of this study, our protocol of using tricortical bone grafts for treatment of malunions and malaligned nonunions of the distal tibia and fibula was safe and effective. This technique can be used with confidence in patients with angular deformities of the tibia and mild shortening of the fibula when other techniques are contraindicated and should be kept in the surgeon's armamentarium. In most cases, this technique allowed correction of the deformity, predictable healing, and an acceptably low complication rate.

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