Intercalary Allograft Reconstructions Using a Compressible Intramedullary Nail

A Preliminary Report

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Abstract

Background Although intercalary allograft reconstructions are commonly performed using intramedullary devices, they cannot generate compression across host-allograft junctions. Therefore, they sometimes are associated with gap formation and suboptimal healing conditions. **Questions/purposes** We describe a new technique and present preliminary results for intercalary allograft reconstructions for tumors using a compressible intramedullary nail.

Patients and Methods We retrospectively reviewed 10 patients (19 host-allograft junctions) who underwent intercalary allograft reconstruction using the compression nailing technique. Two patients were excluded as they had additional vascularized fibular autografts, leaving 15 junctions in eight patients for analysis. Three of the intercalary reconstructions had supplemental plate fixation at one junction. All patients received host bone reamings and cancellous allograft and one had bone marrow aspirate and demineralized bone matrix in addition to the cancellous

allograft. The minimum followup was 3 months (mean, 18 months; range, 3–39 months).

Results Thirteen of 15 junctions healed without additional surgery. Two diaphyseal-diaphyseal junctions did not unite after allograft arthrodeses. One patient underwent revision for nonunion 8 months after the initial procedure, with subsequent healing. The second patient had no evidence of union at 6 months, after which he was lost to followup. There were no allograft fractures or infections in any reconstruction. One patient died of metastatic renal cell carcinoma, and one patient had multicentric local soft tissue recurrences of a periosteal osteosarcoma requiring resection.

Conclusions Our early observations indicate newer compressible intramedullary nails reliably address junctional gap formation, providing for a high rate of union while retaining the long-term benefits of intramedullary stabilization.

Level of Evidence Level IV, case series. See Guidelines for Authors for a complete description of levels of evidence.

Dr. Virkus is a consultant for Stryker Orthopaedics, Mahwah, NJ. Each author certifies that his or her institution 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. This work was performed at Rush University Medical Center.

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Introduction

There are numerous options for reconstruction after resection of a tumor in bone, including endoprostheses [23], intercalary metallic implants [9], and bulk allografts [9]. Allografts can be intercalary, used to fill a diaphyseal defect; osteoarticular, with an intact articular surface; or allograft-prosthetic composites (APCs). Allograft fixation has been performed by various methods, typically consisting of plates and screws [18, 19, 22, 30], intramedullary devices [1, 7, 18, 19, 30, 33, 34], or a combination [18, 33]. Alternative and additional strategies to enhance union include autogenous bone grafting [9], autogenous bone

Fig. 1 A cut-away diagram shows the proximal nail (1) with the internal set screw (4) engaging the partially threaded locking screw (3). The resultant excursion (2) causes movement and compression at the host-allograft junction. (Reprinted with permission of Springer Medizin from Mueckley T, Gonschorek O, Buehren V. Compression nailing of long bones. *European Journal of Trauma and Emergency Surgery*. 2003;29:113–128.)

marrow aspirate [28], bone morphogenic protein [5], bisphosphonate treatment [6], and electromagnetic field exposure [4]. Each method of fixation and augmentation has benefits and drawbacks.

Plate fixation allows controlled compression of the host osteotomy site to the allograft bone [2, 3, 21]. Bony apposition can be confirmed intraoperatively and healing conditions are enhanced. In contrast, fixation with intramedullary devices can induce distraction at the host-allograft junction [2, 10, 15, 21, 26]. In an already compromised healing environment, a residual gap may be substantial and lead to delayed union or nonunion [8, 12, 30]. The allure of intramedullary stabilization is in its superior ability, when compared with plate fixation, to prevent long-term allograft fracture [30]. The ideal implant, then, is one that maximizes junctional healing rate and allograft protection.

Intramedullary devices have been used in the context of traumatic reconstruction for decades [10, 15, 26]. There is continual improvement in design, allowing for increased ease of insertion, strength of stabilization, and biomechanical compatibility. The tendency for distraction at a

fracture site during insertion of the device is not a novel observation [10, 12, 15, 30]. As with allografts, distraction at a primary fracture site also can impede osseous regeneration [12, 24]. Tactics for dealing with this issue include steps as simple as back-tapping a distally fixed implant [12] and use of an external compression device [12]. Several implant companies have included an internal compression screw in their designs for long bone nails (femur, tibia, and humerus) (Fig. 1). This allows for controlled compression intraoperatively at a distracted fracture site to diminish the bony diastasis. Theoretically, if some element of the non-union rate of bulk allografts is attributable to distraction at the host-allograft junction, then decreasing the amount of distraction and adding compression would have a positive effect on healing [8, 30].

We describe the surgical technique to implant such a device and illustrate the healing potential with eight cases.

Patients and Methods

We retrospectively reviewed 10 patients with 19 host-allograft junctions performed using the compression nailing technique. Two of the 10 patients had reconstructions supplemented with a vascularized fibular autograft. Although they achieved healing without incident, the fibula was considered a substantial advantage and the patients therefore were excluded from the final analysis. This left eight patients with nine reconstructions and 15 junctions for definitive analysis. The patients included six men and two women, with an average age of 31.6 years (range, 22–43 years). The histologic diagnoses were periosteal osteosarcoma in two cases, and one each of high-grade intramedullary osteosarcoma, parosteal osteosarcoma, synovial sarcoma, giant cell tumor, aneurysmal bone cyst, and metastatic renal cell carcinoma. The patient with synovial sarcoma had preoperative external beam radiation and chemotherapy. The patient with renal cell carcinoma had external beam radiation 6 months postoperatively. No other patients had perioperative adjuvant treatment. Patients were followed until clinical and radiographic union, failure of reconstruction, or death. Minimum followup was 3 months (mean, 18.1 months; range, 3–39 months). No patients were recalled specifically for this study; all data were obtained from the medical records and review of the radiographs. This study was approved by our institutional review board.

The patients were positioned on the operative table to allow ample access for the tumor resection and subsequent reconstruction. Although the surgical exposure is more extensive than in the case of a fracture, the intramedullary devices are inserted in the standard fashion [10]. Once the allograft is appropriately sized to fit the resected defect, the

proximal segment of host bone and the allograft are overreamed by 2 mm relative to the size of the nail. The distal portion of host bone is overreamed by 1 to 1.5 mm, as recommended by the manufacturer. This allows for ease of nail insertion and subsequent compression while minimizing distraction at the host-allograft interface. The nail must be positioned below the insertion site, as it will migrate during compression. A 5.0-mm partially threaded locking screw then is placed in the proximal dynamic slot, followed by two standard distal locking screws. An axial internal compression screw is inserted in the proximal end of the hollow central canal of the nail until it encounters the dynamic locking screw. Under fluoroscopic observation, the compression screw is advanced, driving the proximal host segment into the allograft (Fig. 2). It is normal to see the screw bend owing to the force, but compression should be halted before screw breakage. This is somewhat subjective and care must be taken during this step. During compression, the junctions should be monitored fluoroscopically and clinically to insure proper alignment and confirm corticocortical contact.

Seven patients had intercalary reconstructions of the femur or tibia, including five allograft arthrodeses, three intercalary allografts, and one APC reconstruction of the proximal humerus (Fig. 3). All reconstructions were performed using a T2 intramedullary nail (Stryker Orthopaedics, Mahwah, NJ). Four of the nine reconstructions were revision procedures, two of nonunions and two of previously infected and treated intercalary arthrodeses. The average length of the allograft segment was 16.9 cm (range, 7–30 cm). Three of the reconstructions had supplemental plate fixation at one diaphyseal-diaphyseal junction (Fig. 4). Reamings from normal host bone and residual cancellous material from the bulk allograft were

placed at all junctions. One patient who had revision of a nonunion, had junctional supplementation with bone marrow aspirate, demineralized bone matrix, and cancellous allograft to augment the healing response.

All patients were allowed touch-down weightbearing initially on the operative extremity and were mobilized on Postoperative Day 1. While in the hospital, they had daily physical therapy and gait training under the supervision of a trained therapist. Assistive devices were used routinely until their weightbearing status was advanced. Patients were discharged home or to a rehabilitation facility at the discretion of the operative team and treating therapists. Home or outpatient physical therapy continued postoperatively as needed. All patients were advanced to full weightbearing 3 months postoperatively.

Routine followup included patient evaluations at 2, 6, and 12 weeks postoperatively. If there were no complications, the appointments were spread to every 3 to 6 months, or as their individual situation dictated. Patients with delayed healing were seen every 1 to 3 months. They were examined clinically and radiographically at each visit. Wound status, pain with weightbearing, ROM (when appropriate), and tenderness at the osteotomy sites were assessed regularly. From the charts we recorded the diagnosis, type of surgical reconstruction, length of followup, healing at last followup, and use of chemotherapy or radiation.

We had radiographic followup for all patients. Assessment of the radiographs was nonblinded and made by collaboration between the two authors. Patients were considered to have achieved union when they had no pain with weightbearing [27] and either the osteotomy line no longer was visible or there was bridging callus on two orthogonal views [30, 34].

Fig. 2A–B Intraoperative fluoroscopic images show closing of the junctional gap (A) before and (B) after compression with the internal screw.

Fig. 3A–B (A) A preoperative radiograph shows a Grade 3 proximal humeral aneurysmal bone cyst. (B) A postoperative radiograph shows the humerus after an APC reconstruction.

Fig. 4A–C (A) A preoperative radiograph shows a femoral periosteal osteosarcoma. Postoperative radiographs show the (B) proximal and (C) distal femur after an intercalary allograft reconstruction. A proximal plate was used for rotational control.

Results

Thirteen of 15 junctions in nine reconstructions had healed at last followup. There were no failures related to allograft fracture, infection, or hardware compromise (Table 1).

One patient had a nonunion of the diaphyseal-diaphyseal host-allograft junction. This was revised 8 months after the index procedure by exchange nailing and local bone grafting. The compression technique was used again, and healing was observed at 6.5 months (Fig. 5). The patient who was lost to followup had radiographic evidence of union of the metaphyseal-diaphyseal junction at 6 months postoperatively; however, the diaphyseal-diaphyseal junction had not united. This patient received preoperative chemotherapy and radiation for treatment of a large synovial sarcoma. We considered his diaphyseal-diaphyseal junction a nonunion. One patient died of metastatic renal

cell carcinoma 20 months after the reconstruction. There was clinical and radiographic evidence of allograft union 8 months postoperatively without subsequent evidence of failure. One patient had multicentric local soft tissue recurrences of a periosteal osteosarcoma requiring local resection. The construct remains intact.

Discussion

The ideal method for bulk allograft fixation remains to be determined. Implants must address the two major noninfectious complications of allograft reconstructions: nonunion and fracture. Reported healing rates vary from 70% to 89%, and the rate of long-term allograft fracture approaches 8% to 20% [1, 7, 18, 19, 30, 31, 33, 34]. The two primary methods of fixation, plates and intramedullary

Table 1. Details of surgical procedures and outcomes

Patient number	Gender	Age (years)	Diagnosis	Site	Reconstruction	Additional material	Reason for plate	Adjuvant therapy	Adverse events
1	M	22	Aneurysmal bone cyst	Proximal humerus	APC				
2	M	28	Giant cell tumor	Proximal tibia	AA				
3	M	33	Synovial sarcoma	Knee	AA	Plate	Rotational stability	Preoperative CTX, XRT	Nonunion
4	M	42	Periosteal osteosarcoma	Diaphyseal femur	IA	BMA, DBM			
5	F	39	Metastatic renal cell carcinoma	Proximal femur	IA			Postoperative XRT	Died of disease
6	M	24	Periosteal osteosarcoma	Distal femur	IA	Plate	Rotational stability		Soft tissue local recurrence
7	F	35	Parosteal osteosarcoma	Distal femur	AA				Nonunion
7	F	35	Parosteal osteosarcoma	Distal femur	AA				
8	M	26	Conventional osteosarcoma	Proximal tibia	AA	Plate	Rotational stability		

APC—Allograft-prosthetic composite, AA—Allograft arthrodesis, IA—intercalary allograft, BMA—bone marrow aspirate, DBM—demineralized bone matrix, XRT—external beam radiation, CTX—chemotherapy.

Fig. 5A–D A preoperative (A) radiograph and (B) MR image show a large intraarticular parosteal osteosarcoma. (C) This patient had a nonunion of the proximal junction of the arthrodesis, (D) which united after an exchange compression nailing.

devices, have unique benefits and weaknesses; however, no difference in healing rates has been elucidated [2, 21, 30]. Plate constructions more predictably provide compression at the host-allograft junction, but it is technically more difficult to align correctly and leaves residual screw holes in the allograft, which is a common site for allograft fracture [30]. Intramedullary devices have a tendency to

leave residual gaps, and lack of compression at the osteosynthesis site may compromise healing, but alignment is technically easier. The most notable benefit to intramedullary stabilization is the diminished rate of long-term allograft fracture compared with that of plates [30]. The most important limitation of intercalary reconstructions using intramedullary devices is the inability to generate

compression across host-allograft junctions, resulting in gap formation and suboptimal healing conditions. Studies have acknowledged inferior allograft healing rates associated with increasingly larger cortical displacement [8, 30]. This typically is categorized as a technical error and is an important mode of failure in allograft reconstructions. Although there is not an absolute maximum acceptable gap established, it may be inferred from previous reports that predictability of union increases as junctional displacement decreases [8, 30]. The use of a compressible intramedullary device addresses the problem of gap formation by allowing for intraoperative manipulation of the junctional distance. We describe our technique with this approach and present the potential for healing achieved by eight patients.

The limitations of our study include the size of the cohort, the short followup, lack of a control group, and variability of reconstructions. The small number of patients is a result of the recent availability of this technique combined with the relatively low frequency of bulk allograft reconstructions. We believe the relatively short duration of followup does not negate the findings in the limited scope of this analysis. One patient was lost to followup after 6 months, although some reports of bulk allografts suggest they can unite long after 6 months [1, 18]. Our goal was to provide an initial presentation of this technique and report our early observations. We believe it is imprudent to comment further regarding long-term outcomes or to compare with other methods of fixation at this juncture.

One of our patients had postoperative radiation and one had preoperative chemotherapy and radiation. Two patients had a remote history of adjuvant cancer therapies, however, we believe they were not a major biologic consideration in the current reconstructions. Specifically, the patient with the soft tissue recurrence of a periosteal osteosarcoma received chemotherapy and radiation for his recurrence, by which time the reconstruction had healed. The patient with a conventional osteosarcoma underwent revision surgery for an infection. His chemotherapy was completed 12 years before his allograft revision. Many patients who undergo bulk allograft reconstructions require perioperative adjuvant therapies. Although not shown conclusively across the literature, adjuvant treatment should be considered an independent risk factor for delayed union or nonunion [8, 14, 22]. We had only had two patients with relevant adjuvant treatment, one of whom had nonunion, but can draw no conclusions regarding risk factors owing to the small numbers.

One of the patients underwent an intercalary reconstruction for metastatic renal cell carcinoma. Although often treated with operative stabilization alone, with or without intralesional curettage [17], we elected to perform an en bloc resection and allograft reconstruction after

preoperative embolization. This young patient had an isolated metastasis to her proximal femoral shaft. This lesion was relatively easily resectable and reconstructable with an intercalary allograft. There is some evidence that there is a survival benefit with en bloc resection of an isolated renal cell bone metastasis [29], although this was not replicated in a subsequent study [17]. Regardless, this tumor is relatively chemotherapy and radiation resistant [17], and we thought complete excision of the tumor would be the most appropriate treatment for this patient to obtain local control.

The use of additional plates, bone graft, and vascularized fibulae is more a function of the nature of the disease than the method of fixation [13, 25, 32]. The decision to augment the reconstruction was based on the size of patient, residual length of host bone, and rotational stability. These decisions were made on a case-by-case basis. Although this may diminish the purity of the cohort, variability is inherent in these operations. Plates were used at the discretion of the operating surgeon (WWV) and continue to be used regularly at the diaphyseal-diaphyseal junction. The primary indication is rotational control. The compression provided by the nail will provide some rotational stability from the static interaction of the allograft and host bone. However, it is not uncommon to observe limited allograft resorption at the junction, and the addition of a plate aids in stability in this circumstance.

Locking screw breakage remains an issue with intramedullary fixation [11, 16]. It is imperative that the largest locking screw available, in most cases 5 mm, is used for compression. With screws of 5 mm, Gonschorek et al. estimated locking screw breakage at less than 2% [10]. Mueckley et al. warned against overtightening and recommended stopping compression when the screw begins to bend, applying no more force than one would use with normal cortical screw insertion [20]. Anecdotally, compression should be stopped when there is adequate corticocortical contact of the junctions, verified clinically and fluoroscopically, the compression screw is unable to be turned further without excessive torque, or the locking screw begins to cut through the host bone.

The limitation of intramedullary implants for this use, and a relative benefit of plate fixation, has been the difficulty in minimizing the host-allograft junction distance. Gaps can be diminished or obliterated using an internally compressible intramedullary nail. Implants for this use are readily available, and the surgical technique is a simple extension of current practice. Our early observations indicate newer compressible intramedullary nails have high union rates while retaining the protective effects of intramedullary stabilization in bulk allografts. Additional studies, including larger cohorts and direct comparisons to a control group, are needed to further elucidate any definite advantage.

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