

ORIGINAL ARTICLE

Allograft Arthrodesis of the Knee in High-grade Osteosarcoma

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Background: A retrospective cohort study was conducted to evaluate the outcomes of massive allograft arthrodesis in the management of high-grade osteosarcoma around the knee.

Methods: The results of 19 patients with high-grade osteosarcoma around the knee, which was treated by wide resection and reconstruction using allograft arthrodesis, were evaluated for a mean length of 7.3 years (range, 3–13 years). The mean age at the time of surgery was 13.3 years (range, 6–27 years). According to the Musculoskeletal Tumor Society staging system, 17 patients were stage IIB and 2 were stage IIIB at presentation. Evaluations were based on the oncologic results, non-oncologic results and complications. Functional evaluation was performed with the Enneking functional evaluation form.

Results: Four patients (21.1%) died of their disease; 3 (15.8%) are alive with disease; and 12 (63.2%) are free of disease. Four patients (21.1%) had local recurrence of their tumor at a mean of 23 months postoperatively (range, 9–44 months). The mean time to union of the metaphyseal junction was 24.7 weeks (range, 16–30 weeks) and the diaphyseal junction was 47 weeks (range, 24–78 weeks). The overall complication rate was 31.6%, including 2 (10.5%) infections, 3 (15.8%) allograft fractures, and 1 (5.3%) nonunion. Our mean final functional result was 65%.

Conclusion: Due to the high rate of complications in this study, we conclude that allograft arthrodesis should be left as a salvage or “back-up” reconstructive procedure after resection of osteosarcoma around the knee, unless there are special indications for this procedure. We found allograft fracture to be the most common complication.

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Key Words: allograft, knee arthrodesis, osteosarcoma

Introduction

Resection of extremity osteosarcoma results in loss of muscles, large bone defects and, sometimes, loss of entire joints. The options for reconstruction after resection of a bone tumor about the knee include the use of a custom total knee prosthesis, an osteoarticular allograft or an allograft-joint replacement composite, an arthrodesis with intercalary bone-grafting, or conversion to a rotationplasty. The choice of reconstruction is dependent on several factors,

including the extent of tumor, the remaining bone and soft tissue, and the patient's physical demands and expectations.

Local resection and arthrodesis for tumors about the knee was first described in 1908 by Lexer.^{1,2} During the last 15 years, the method has been abandoned because of the major concern of total loss of postoperative knee function. With the advance in tumor prosthesis, limb and joint salvage procedures using large custom-made prostheses, sometimes combined with massive allografts,^{3,4} became a more

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preferable procedure. There is, however, some suspicion about the longevity of these prostheses.⁵ On the other hand, successful resection–arthrodesis provides a durable, functional and stable limb. This option was furthermore presented to patients as an alternative allowing them to take part in an active life with no restrictions, other than an immobile knee.

There have been several studies to evaluate the results of resection–arthrodesis in the treatment of a tumor.^{6–9} It was quite successful in controlling the tumor, but an increase in complications, including infection, nonunion and late fatigue fracture, made rehabilitation long and difficult. In the present study, we tried to determine the oncologic, surgical and functional results, and the complications of allograft arthrodesis of the knee in the management of high-grade osteosarcoma.

Methods

Between January 1991 and March 2001, 19 patients with high-grade osteosarcoma around the knee were treated by wide resection and reconstruction using allograft arthrodesis. All underwent neoadjuvant and adjuvant chemotherapy. The regimens employed contained high-dose methotrexate, doxorubicin, cisplatin and ifosfamide, and they generally followed the protocols employed by the Pediatric Oncology Group.¹⁰ Our indications for arthrodesis were skeletally immature patients or extensive involvement of tumor, especially jeopardizing the extensor mechanism. Furthermore, we discussed extensively with the patient (and family) preoperatively regarding the various options for reconstruction and their functional consequences.

Ten patients were female and 9 were male. The mean age at the time of surgery was 13.3 years (range, 6–27 years). All patients were evaluated by clinical examination, plain roentgenography, computed tomography (CT) and magnetic resonance imaging of the primary lesion, radionuclide bone scanning, and plain chest roentgenography or CT alone. They were staged by the Musculoskeletal Tumor Society staging system¹¹ following needle or incisional biopsy. There were 17 patients with Stage II lesions and 2 with metastatic disease (Stage III) at presentation. The tumor involved the distal femur in 12 patients and the proximal tibia in 7 patients. Mean follow-up was 7.3 years (range, 3–13 years).

All patients underwent an attempted wide or radical resection of the primary tumor. A long midline approach was made to the distal half of the femur and

proximal tibia, followed by identification and displacement of the neurovascular bundle. Marking of the anterior cortex of the femur and tibia before resection helped to position the distal part of the reconstructed extremity in the desired amount of rotation. The lower limb was expected to be placed in 5–10° of external rotation, with the hip in neutral rotation. Wide resection was then performed and confirmed by frozen sections. Fixations were completed using intramedullary rod, or broad A-O dynamic compression plates, or a combination. Rotational and bending stability of the junctions was examined, and the final position of the allograft was verified on intraoperative radiographs. Corticocancellous bone chips (15 autogenous, 4 allogeneous) were applied primarily around the osteotomy site. Local muscle flaps (e.g. gastrocnemius) with split-thickness skin grafts were employed as needed to achieve both tension-free closure and soft-tissue coverage of the allograft. Patients were given cefazolin and gentamycin from the day of operation throughout the first postoperative week. Oral antibiotics were recommended for the ensuing 2 weeks. Cast immobilization was used for 1–3 months (mean, 2.4 months) depending on the type of fixation and the clinical evidence of union. The patient was allowed to have toe-touch weight bearing as soon as the incision healed, which then progressed to full weight bearing over the next 4–6 months. Patients were followed up at approximate intervals of 2–4 months. Serial radiographs of the limb, radiographs of the chest, and CT scans were obtained to determine the presence of metastatic disease.

All allografts were procured in a sterile fashion and stored at –80°C until used. When the graft was removed from the freezer and opened in the operating room, it was cultured for aerobic and anaerobic organisms and thawed in warm saline solution with antibiotics. It was cleaned of unneeded soft tissue and bone marrow.¹² The allograft was matched primarily by size, if possible, so that the diameters of the intramedullary canals of the allograft and host bone were within several millimeters of each other at the level of the planned diaphyseal junction after the arthrodesis. For patients who had little or no further skeletal growth, we aimed to leave the limb about 1–2 cm shorter than the contralateral limb to facilitate the swing phase of walking. For patients who had more than 1 year of potential skeletal growth remaining, we expected to lengthen the limb by 2–4 cm to accommodate future growth of the contralateral limb. The mean length of the allograft was 19.5 cm (range, 12–30 cm).

For radiographic evaluation, union was defined as evidence of bridging callus or continuity of cortex in standard anteroposterior and lateral radiographs.¹³ We defined a metaphyseal junction as one between the metaphyseal end of the allograft and the metaphyseal bone of either the distal part of the femur or the proximal end of the tibia, depending on the site of the tumor. A diaphyseal junction was defined as that between the diaphysis (that is, cortical bone) of the allograft and the remaining part of the diaphysis of the proximal part of the femur or the distal end of the tibia. Functional evaluation was performed with the system of the Enneking functional evaluation form (Table 1).¹¹ The evaluation form contains 6 factors. Descriptive terms such as excellent, good, fair, or poor are not assigned to a specific numeric range; rather, the result is expressed as the proportion of expected normal function for the patient. When each of the factors has been scored, the sum of the individual factor scores is calculated for a total score. The maximum possible score is estimated by multiplying the number of factors by 5. The rating percentage is determined by dividing the maximum score into the total score.

Results

Regarding oncologic outcomes, 4 patients (21.1%) died of their disease in a mean of 3 years (range, 1–6 years). Three patients (15.8%) developed pulmonary metastases after surgery, but remain alive with disease. Among the remaining 12 patients (63.2%), 2 had 1 or more pulmonary metastasectomies; currently, all 12 patients are free of disease. Four patients (21.1%) had local recurrence of their tumor in a mean of 23 months (range, 9–44 months) postoperatively. Two of these patients eventually had an amputation. Another 2 patients died of pulmonary metastases.

Regarding the surgical results, the mean time to union for the metaphyseal junction was 24.7 weeks (range, 16–30 weeks), and that for the diaphyseal junction was 47 weeks (range, 24–78 weeks) (Figure 1). Mean operation time and blood loss were 4.6 hours (range, 3.5–8.5 hours) and 2,100 mL (range, 1,600–4,800 mL). Wide margins were attempted in all cases; the resection margins were considered to be wide in 18 cases and marginal in 1, by postoperative pathologic analysis. No intraoperative complications

Table 1. Enneking functional evaluation form

Score	Pain	Function	Emotional acceptance	Supports	Walking	Gait
5	None	No restriction	Enthusied	None	Unlimited	Normal
4			Intermediate			
3	Modest	Recreational restriction	Satisfied	Brace	Limited	Minor cosmetic
2			Intermediate			
1	Moderate	Partial disability	Accepts	1-cane crutch	Inside only	Major cosmetic, minor handicap
0	Severe	Total disability	Dislikes	2-cane crutch	Unable unaided	Major handicap

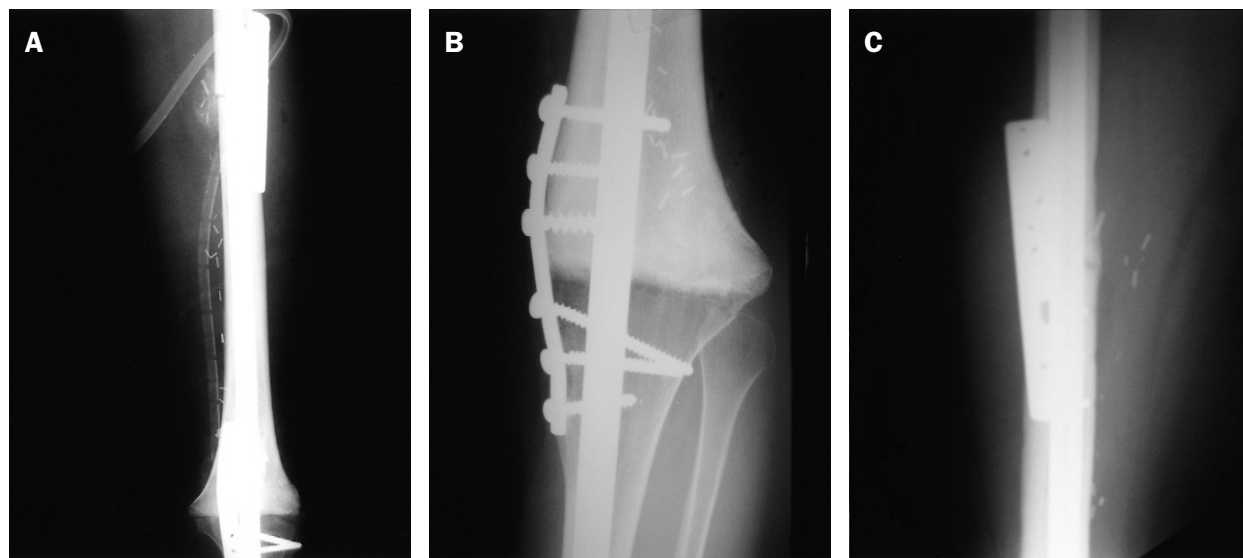


Figure 1. A 13-year-old girl with distal femur osteosarcoma of the left leg: (A) immediate postoperative X-ray; (B) solid union over the metaphyseal junction was achieved 16 weeks postoperatively; (C) solid union over the diaphyseal junction was achieved 26 weeks postoperatively.

were recorded for any of the 19 patients, but 6 (31.6%) postoperative complications occurred, including 2 (10.5%) infections, 3 (15.8%) allograft fractures, and 1 (5.3%) nonunion. Infection in the 2 cases was superficial and developed immediately after the operation. After adequate debridement and appropriate antibiotics, the wounds healed without sequelae. Three (15.8%) allograft fractures occurred in a mean of 4.2 years (range, 3–5.6 years) postoperatively. One of the 3 cases had an accident 3 years after surgery, in which she fell down; she was treated with revision allograft arthrodesis, including removing the fractured allograft as well as previous hardware, and reconstruction with another allograft and bone grafting (Figure 2). Another patient refused further treatment because of multiple pulmonary metastases and eventually died of the disease. In the other patient, the fracture occurred 5.6 years postoperatively but was left alone until the seventh postoperative year when the nail was angulated to 90° and complicated with severe pain. Finally, the previous

allograft and hardware were removed to correct the angulation and the limb was lengthened with Ilizarov external fixators (Figure 3). The only patient with nonunion was treated with a second reconstructive operation with a new allograft. The final mean functional result was 65% (range, 26–85%) according to the Enneking functional evaluation system.

Discussion

Many factors must be considered when choosing the reconstruction method after resection of a tumor about the knee, including the type and extent of the tumor, the amount of tissue that must be removed to attain the desired margin, the experience of the surgeon with the different reconstructive procedures, an understanding of the advantages and disadvantages of the reconstructive operations, and the needs and preferences of the patient. An arthrodesis may be the

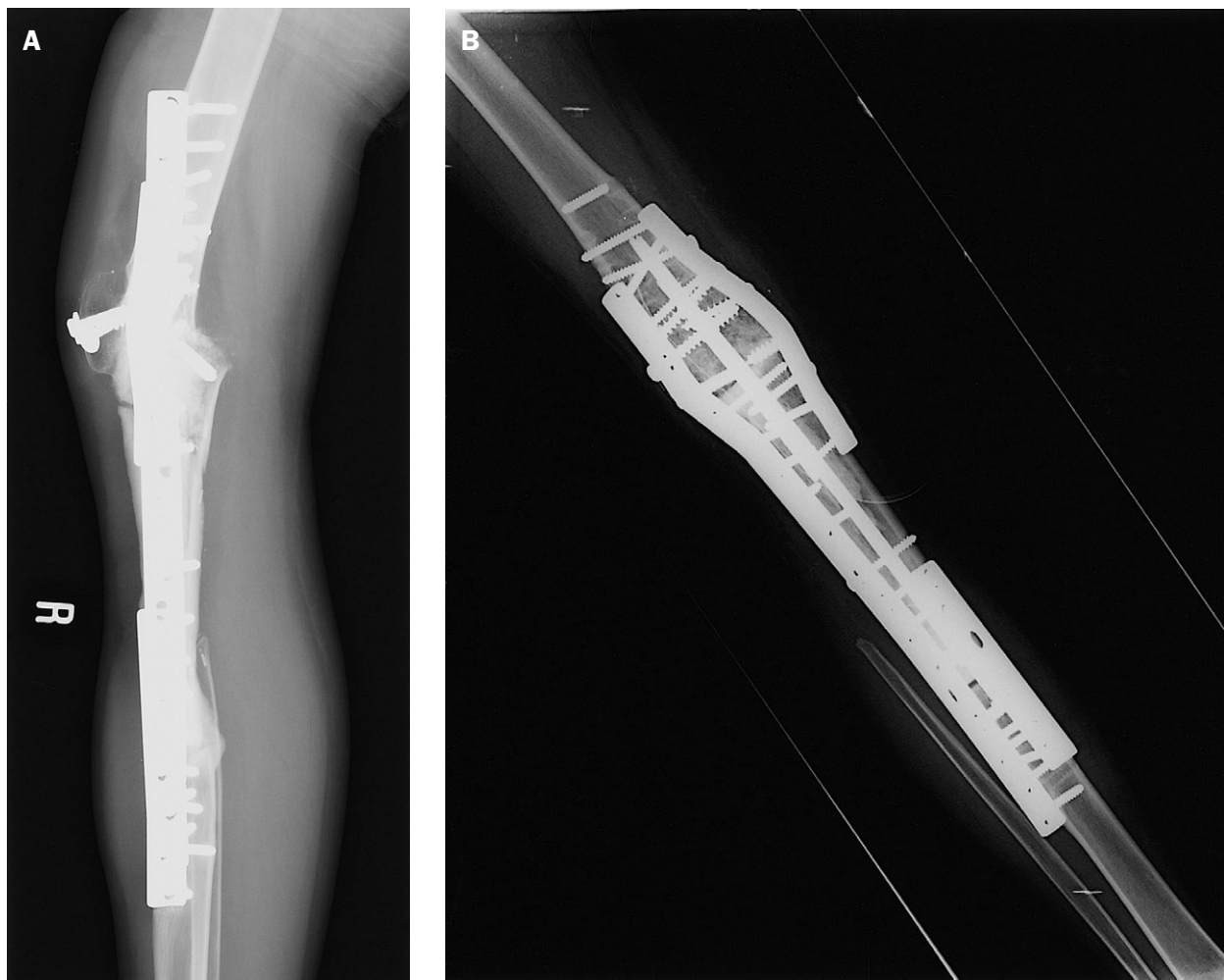


Figure 2. An 18-year-old girl with proximal tibia osteosarcoma of the right leg: (A) an allograft fracture was noted on X-ray 3 years postoperatively; (B) an immediate postoperative X-ray shows revision with a new allograft augmented with bone cement.

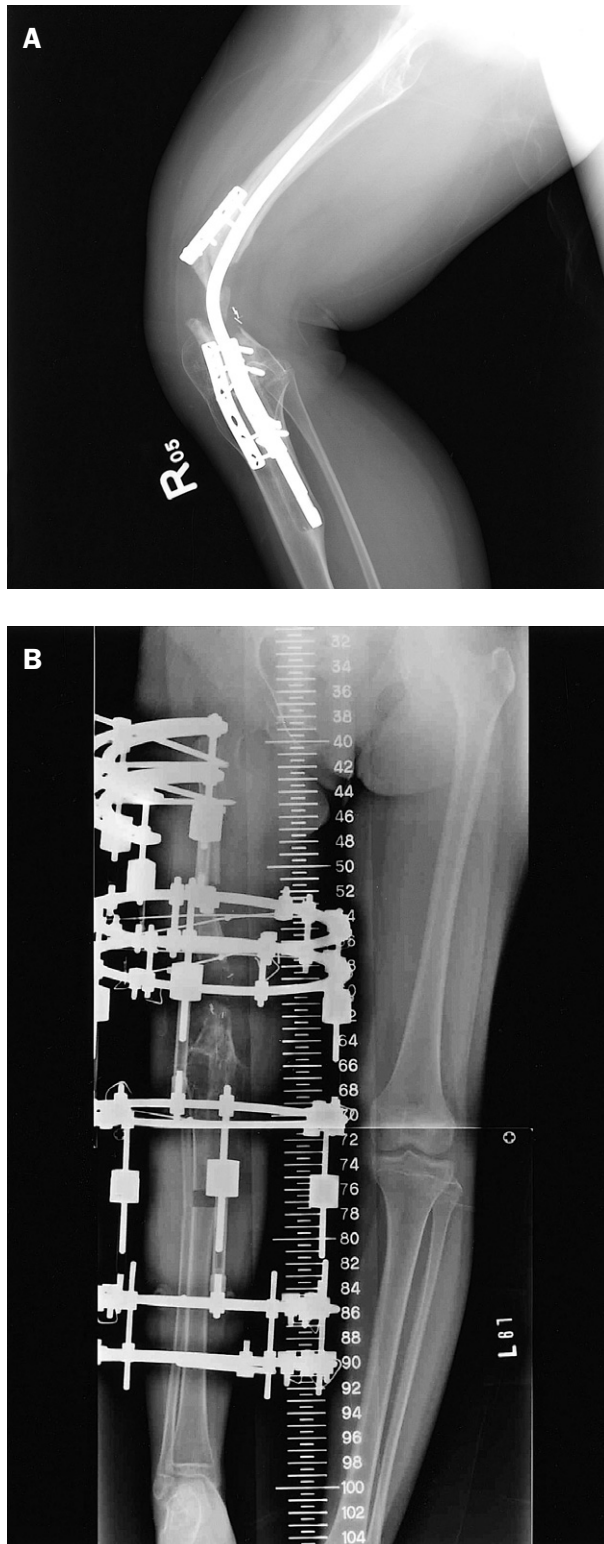


Figure 3. A 7-year-old girl with left distal femur osteosarcoma was treated with resection–arthrodesis and allograft reconstruction. (A) At the 7-year postoperative follow-up, an X-ray shows that the nail has angulated to 90°; the patient was in severe pain. (B) The immediate postoperative X-ray shows that the previous allograft and hardware have been removed, correcting the angulation and lengthening with Ilizarov external fixators.

best option of reconstruction for some patients because of their age, weight or desired level of activity, or because the extent of resection of bone or soft tissue makes an arthroplasty impossible. An arthrodesis may also be indicated as a salvage or back-up procedure after a prosthetic replacement or an osteoarticular allograft has failed. Furthermore, an immovable knee in a good alignment and position can be an appropriate sacrifice to achieve a stable, pain-free implant for the rest of the patient's life.

The major concern of allografts lies in its high complication rate. Benevenia et al,¹⁴ in a follow-up of Makley's initial series, evaluated 19 patients who had been managed with an allograft stabilized with an intramedullary nail. They reported good results, but non-oncologic complications were found in 8 patients. Others have found similar results.^{15,16} In the present study, the authors arrived at the same conclusion, with allograft complications occurring in 31.6% of patients, including 2 (10.5%) patients with infections, 3 (15.8%) with allograft fractures, and 1 (5.3%) with nonunion. The 2 infections occurred in our early patients in whom local rotation flaps were not used routinely. We attributed the infection to the magnitude of the soft-tissue resection and inadequate soft-tissue coverage of the graft to fight infection.

Among the complications in this study, allograft fracture was the one with the highest incidence (15.8%; 3 patients). Of the 3 patients, 1 was managed with revision allograft augmented with polymethylmethacrylate and intramedullary rod fixation to achieve solid union and good functional performance. Another patient who was managed with removal of the allograft and Ilizarov's apparatus fixation had refused early intervention until the previous intramedullary rod had bent 90°. For allograft arthrodesis, special techniques have been advocated to reduce the complication of allograft fracture. Avoiding screws in the allograft is 1 key technique because a screw hole would create a stress riser point and induce excessive allograft resorption mediated by osteoclasts that often leads to allograft fracture. We also recommend early intervention with bone-grafting and supplemental fixation in case there is radiographic evidence of instability, such as increasing radiolucency along the nail, especially when accompanied with pain or tenderness at the junction site. Filling the medullary canal of the allograft with polymethylmethacrylate cement seems to lower the incidence of fracture, but larger series should be conducted to confirm this result.

The oncologic outcomes for patients in the current study are similar to those reported in another series,¹⁷ and it does not appear that limb salvage procedures are

associated with a worse disease outcome. However, our local recurrence rate of 21.1% (4 patients) can be attributed to the initial severity of the disease (2 patients were stage IIIB) and younger age. As we know, the knee joint is a more superficial joint. In young children, the soft tissue envelope is far from sufficient to allow for a wide marginal resection. Our final functional results showed a persistently high level of function with an Enneking functional score of 65%.

In selected patients, resection arthrodesis with massive bone allografts is an effective reconstructive method for the management of high-grade osteosarcoma about the knee. However, allograft complications are a major concern. Among the complications, allograft fracture has the highest incidence.

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