Title: An intramedullary free vascularized fibular graft combined with pasteurized autologous bone graft in leg reconstruction for patients with osteosarcoma

Names of authors

Masataka Noguchi, Hiroo Mizobuchi, Motohiro Kawasaki, Eiki Ueta, Yusuke Okanoue, Yoshimichi Taniwaki, and Toshikazu Tani

Academic affiliation

Department of Orthopaedic Surgery, Kochi Medical School, Japan

Reprint requests

Dr. Noguchi, Dept. of Orthopaedic Surgery, Kochi Medical School, Nankoku, Kochi 783-8505, Japan

FAX: 81/88-880-2388

PHONE: 81/88-880-2387

e-mail address: noguchim@kochi-u.ac.jp

**Abstract**

The use of pasteurized autologous bone graft has been an innovation in limb-salvage surgery; however, the principal disadvantage of pasteurized bone graft is fracture, infection, pseudoarthrosis, and bone resorption. The authors present two cases in which an intramedullary free vascularized fibular graft combined with pasteurized autologous bone graft was performed for immediate femur or tibia reconstruction following osteosarcoma resection. The rationale of this method is to combine the mechanical strength of a pasteurized bone with the biological activity of a vascularized bone. The pasteurized bone graft provides bone stock and early stability, while the addition of the vascularized bone graft substantially facilitates host-pasteurized bone union. This combination procedure may be a recommended option for reconstruction of the lower leg preserving knee joint function for patients with osteosarcoma.

Key words: Osteosarcoma, , Vascularized bone graft, Pasteurization

## Introduction

Limb salvage surgery for the treatment of malignant bone tumor is an acceptable alternative to amputation in most patients as improvement has been achieved in neoadjuvant chemotherapy, and operative techniques. Pasteurized autologous bone graft is a relatively new method to reuse resected and diseased autologous bones after heat treatment at a comparatively low temperature (60-65°C for 30-40 min).[1,2,3] Although pasteurized bone grafting has bone-inducing properties, many complications, such as fracture, infection, pseudoarthrosis, and bone resorption due to a biological fault with pasteurized bone, have been reported.[4,5,6] With vascularized bone grafting, which involves grafting a viable bone while preserving its blood flow, rapid bone union can be obtained regardless of the length of the graft.[7,8] Furthermore, because the bone is richly vascularized, it is highly resistant to infection.[9,10] The rationale for using a pasteurized bone graft with a vascularized bone graft is to combine the mechanical strength of the pasteurized bone graft with the biologic activity of the vascularized bone graft. We employed an intramedullary free vascularized fibular graft combined with a pasteurized bone graft in the reconstruction of a femur or tibia with osteosarcoma to compensate for

the biological fault of pasteurized bone, and we present here two patients and our operative procedure.

**Operative procedure**

The sarcoma within the femur or tibia was resected with a wide curative margin. During pasteurization of the resected bone, the vascularized fibula was harvested from the ipsilateral or contralateral leg. The longest amount of bone flap available was harvested. The pasteurized bone was reamed so that the fibula bone flap would fit easily but securely within the medullary canal of the pasteurized bone. A slit of about 1-cm width was created at the proximal or distal portion of the pasteurized bone as an exit for the pedicle of the intramedullary fibula bone flap. The fibula bone flap was inserted into the medullary canal of the pasteurized bone so that at least 1 cm of the bone flap was available to be inserted into the host bone canal at each end. The vascular pedicle of the fibula bone flap was brought out through the side slit. Microvascular anastomosis of the vascular pedicle to the recipient vessels was performed. End-to-end anastomosis was performed to branches of the femoral vessels or to the peroneal or the tibial vessels. Pre-selected plates and screws etc. were used to fix the pasteurized bone-fibula flap unit

to the host bone after microvascular anastomosis.

**Case reports**

**Case 1** The patient was a 15-year-old boy with an osteosarcoma of the left proximal tibia. He received two cycles of neoadjuvant chemotherapy consisting of methotrexate, cisplatin, and daunorubicin. In October 2002, he received a free vascularized fibular graft combined with pasteurized autologous bone graft for leg reconstruction. During the surgery, 12 cm of the proximal tibia was then resected to preserve the proximal epiphyseal growth plate, and a 19-cm fibula bone flap was harvested from the contralateral leg. The fibula bone flap was placed into the medullary canal of the intercalary pasteurized bone graft. Proximally, 1 cm of the fibula bone flap was inserted into the host tibia and distally, 6 cm of the fibula bone flap was inserted into the host tibia tightly. The vascular pedicle of the flap was brought out through a 1-cm width slit of the pasteurized bone graft. Microvascular anastomoses were performed end-to-end to the peroneal artery and end-to-end to the tibial vein. After microvascular anastomosis, the pasteurized bone graft and host tibia were secured with staples, plates, K-wires, and screws. Postoperatively, the patient received two more cycles of chemotherapy. At five

months, radiographs showed bone union at the distal junction and the patient was allowed partial weight bearing on the affected leg. The patient was allowed full weight bearing at seven months after operation, and internal fixation was removed at 21 months after operation. At four years after operation, the patients showed no local recurrence of osteosarcoma and he could flex his affected knee joint in the full range without any late complications(Fig. 1).

**Case 2** The patient was a 12-year-old boy with an osteosarcoma of the left distal femur. He received no neoadjuvant chemotherapy because preoperative biopsy revealed a parosteal osteosarcoma which did not need chemotherapy.[11] In July 2006, he received a free vascularized fibular graft combined with a pasteurized autologous bone graft for leg reconstruction. During the surgery, 18 cm of the distal femur was resected to preserve the distal epiphyseal growth plate, and a 24-cm fibula bone flap was harvested from the contralateral leg. The fibula bone flap was placed into the medullary canal of the intercalary pasteurized bone graft. Proximally, 4 cm of the fibula bone flap was inserted into the host femur tightly, and distally, 1 cm of the fibula bone flap was inserted into the host femur. The vascular pedicle of the flap was brought out through a

1-cm width slit of the pasteurized bone graft. Microvascular anastomoses were performed end-to-end to the side branchies of the femoral artery and femoral vein. After microvascular anastomosis, the pasteurized bone graft and host femur were secured with a locking plate and screws. The patient was allowed partial weight bearing on the affected leg three months after operation. At seven months, radiographs showed bone union between the fibula bone flap and host femur at the proximal junction. The patient was allowed full weight bearing at nine months after operation. At one year after operation, the patients showed no local recurrence of osteosarcoma (Figure 2). He could flex his affected knee joint from in the almost full range (0-125 degrees) and could play athletic sports without any late complications.

**Discussion**

Several surgical procedures have been reported for bony defects after tumor surgery. Prosthetic replacement is an option for limb salvage surgery, but loosening, breakage, and wear are encountered during long-term follow up.[12,13] Alografts are also commonly used for reconstruction surgery but allografts require a bone bank system, and there are concerns about immunologic responses, transmission of diseases, religious and social

circumstances, and a high complication rate including nonunion, fracture, and infections.[13,14,15,16,17] The pasteurized autologous bone graft is a relatively new and reasonable substitute for allografts to reuse resected and diseased autologous bones after heat treatment at a comparatively low temperature (60-65℃ for 30-40 min).[1,2,3] Bone induction is produced by the response of mesenchymal cells in the recipient bed to BMP transferred from the bone implant; however, at thermal exposure of 70 ℃ and greater for one hour, or irradiation sterilization, the biological activity of BMP is destroyed.[4,18] Pasteurization has a lethal effect on malignant cells while preserving sufficient biomechanical strength and bone-inducing properties.[1,2,3,19] Although pasteurized bone grafting has bone-inducing properties, many complications such as fracture, infection, pseudoarthrosis, and bone resorption due to a biological fault of pasteurized bone have been reported.[4,5,6] Vascularized bone grafts possess a number of advantages. They do not rely on the recipient bed for revascularization and incorporation. The stage of creeping substitution is bypassed, with more rapid developments of bone union and biomechanical strength.[7,8] Furthermore, since the bone is richly vascularized, it is highly resistant to infection.[9,10] The rationale for combining a pasteurized bone graft with a

vascurazized bone graft is to exploit the advantages of each. The pasteurized bone graft provides bone stock and early mechanical stability, and the vascularized bone graft substantially improves the biological properties of the reconstruction. In 2004, Chang[20] reported two cases in which a vascularized fibula bone flap was used with an intercalary allograft for immediate femur reconstruction following sarcoma resection. Although we report a similar method for lower limb salvage surgery in this article, we believe that the pasteurized bone graft is more advantageous than an allograft as the host bone because pasteurized bone grafting has bone-inducing properties and an anatomically suitable shape. The vascularized fibula graft can be assembled with the pasteurized bone graft, using either an intramedullary or onlay technique. We prefer to insert the fibula bone flap concentrically into the canal of the pasteurized bone graft because the fibula bone flap can serve as a viable intramedullary nail. Although the vascular pedicle is brought out through the side slit (1-cm width) of the pasteurized bone graft in our technique, we believe that this may not weaken the mechanical strength of the pasteurized bone graft. The length of the fibula bone flap must exceed the bone resection by at least 5 cm, so that several cm of fibula bone flap can be inserted into both the proximal and distal host

bone. Although a number of technical issues need further refinement, the combination of a vascularized fibular graft and intercalary pasteurized bone graft may be a recommended option for reconstruction of the lower leg preserving knee joint function for patients with osteosarcoma. This procedure fit especially for the growing young patients in which chemotherapy is effective and reduction surgery preserving the surrounding soft tissue of tumor can be performed.

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Figure legends

Figure 1 A 15-year-old boy with an osteosarcoma of the left proximal tibia

A: Before operation

B: Immediately after operation

C: Radiograph at four years after operation shows excellent healing at both the proximal and distal junctions.

Figure 2 A 12-year-old boy with a parosteal osteosarcoma of the left distal femur

A: Before operation

B: An 18 cm of the distal femur was resected to preserve the distal epiphyseal growth plate. After pasteurization, a slit of 1-cm width was created at the proximal of the pasteurized bone as an exit for the pedicle of the intramedullary fibula bone flap.

C: A pasteurized bone graft was secured with a locking plate and screws after microvascular anastomosis.

D: Radiograph at one year after operation shows excellent healing at both the proximal and distal junctions.

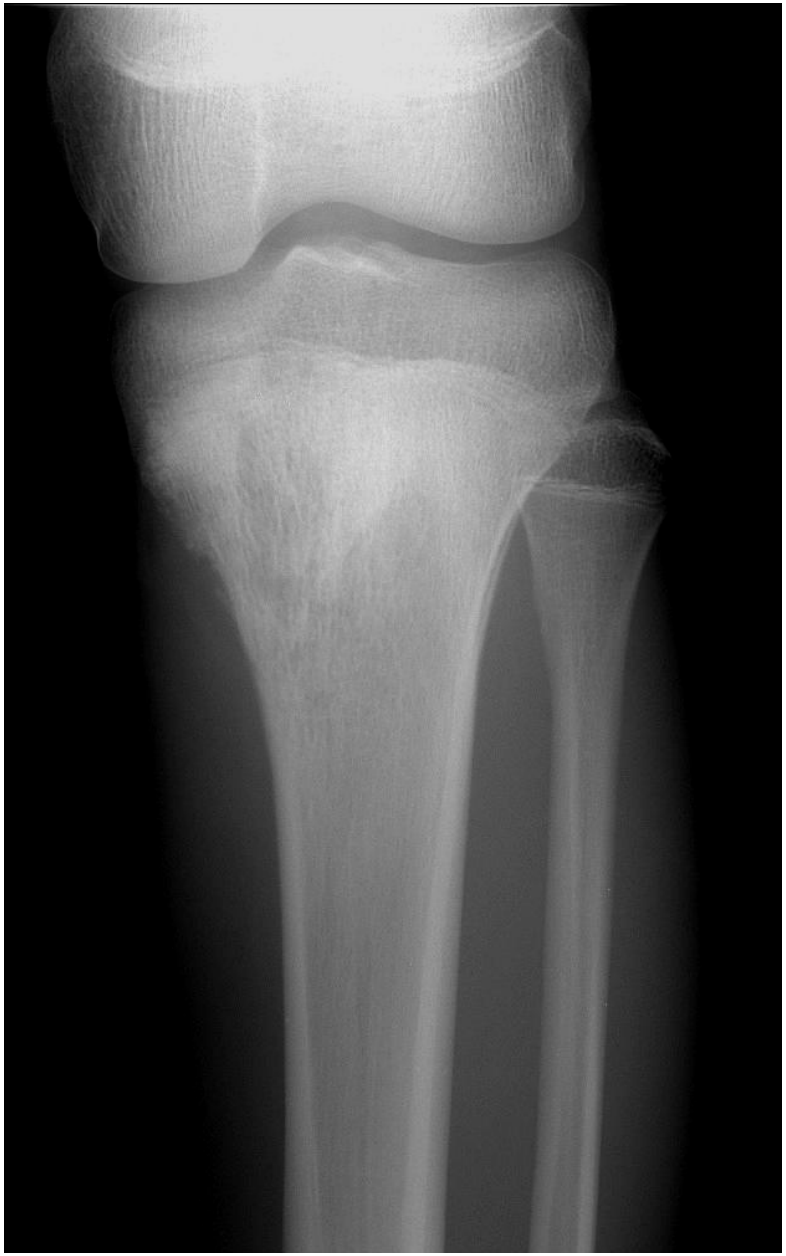

Figure 1A

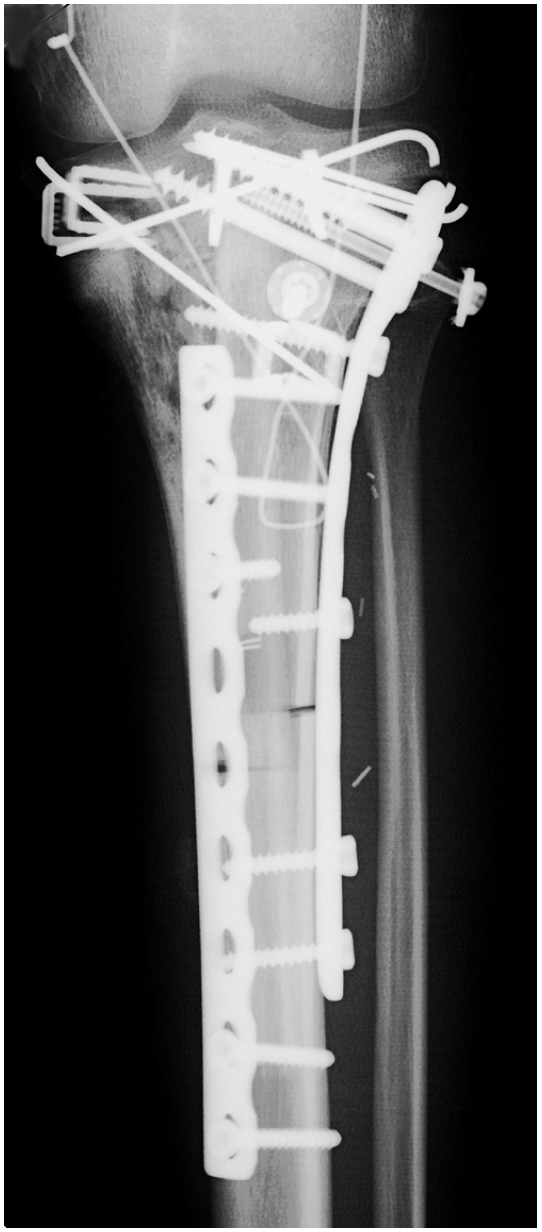

Figure 1B


Figure 1C

Figure 2A

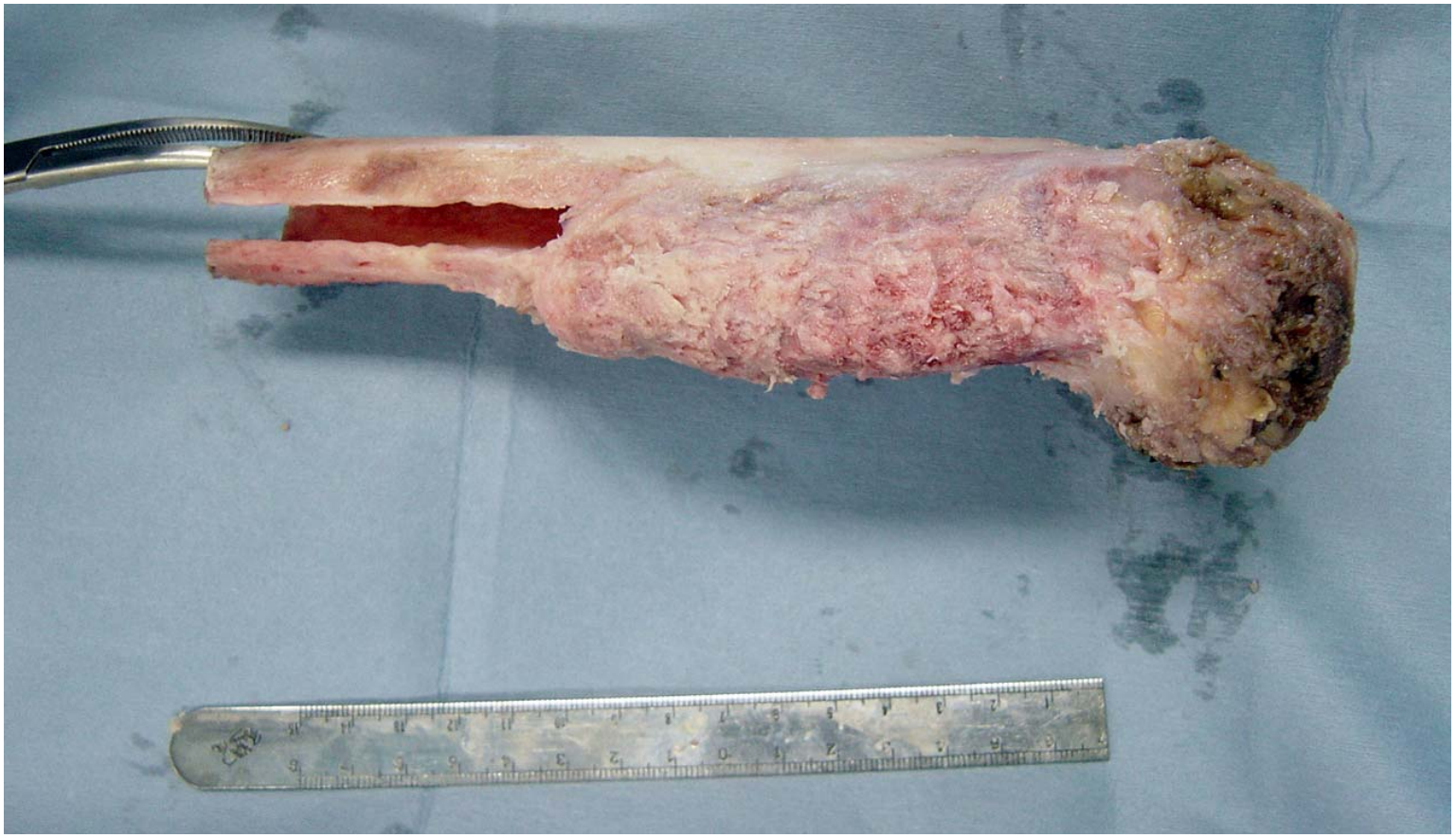

Figure 2B

Figure 2C

Figure 2D