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CASE REPORT
Reconstructive

Vascularized Fibular Grafts for Failed Liquid Nitrogen–treated Autografts in the Humerus: Report of Two Cases

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Summary: With advances in chemotherapy and surgical techniques, limb salvage and biological reconstruction, including autologous bone grafting, have become the preferred treatment options for primary malignant bone tumors of the extremities. Although autografts, which involve recycling of tumor-bearing bones, have the advantages of easy accessibility and anatomical matching, fracture is a frequent major complication. However, to our knowledge, salvage of refractory autograft failure has not yet been reported. This report describes free vascularized fibular graft implantation for salvaging failed previous reconstructions. We describe two patients (a 4-year-old girl and a 30-year-old man, respectively) with primary malignant bone tumors. Liquid nitrogen-treated autografts had been used to reconstruct the humerus in both cases. The patients sustained autograft fractures that could not be treated conservatively or by internal fixation. Free vascularized fibular grafts were transferred as double-barrel inlay grafts (length 7.2 and 8.2 cm) and a single-strut onlay graft (length 16 cm). The brachial arteries, brachial veins, and cephalic veins were used as recipient vessels. Bone union between the fibular grafts and humerus was achieved after 29 and 15 months of follow-up, respectively. In conclusion, free vascularized fibular grafts can be used to salvage refractory autograft fractures. *(Plast Reconstr Surg Glob Open 2023; 11:e5166; doi: 10.1097/GOX.0000000000005166; Published online 4 August 2023.)*

Significant advances have been made in the treatment of primary malignant bone tumors.[1] Limb salvage surgery involves various methods of reconstructing skeletal defects, including endoprostheses and biological reconstruction.[2] Biological reconstruction materials are classified as vascularized (including free vascularized fibulas and distraction osteogenesis) and nonvascularized (including allogenic bone and recycled autografts).[2] Recycling of autologous tumor-bearing bone treated by irradiation, pasteurization, or liquid nitrogen is preferred in centers where use of allografts is limited. Autologous bone has the advantages of easy morphological matching and not requiring a large bone bank.[3]

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With the increased survival of patients with malignant bone tumors, bone healing after limb-salvaging surgery presents a difficult challenge. The long-term survival rate of autologous bone grafts is approximately 40%, which is comparable to that achieved by other biological reconstruction methods.[4–6] However, to our knowledge, no report has yet described salvage after autograft failure. We present here two cases of humeral fractures after frozen autograft salvaged by free vascularized fibular grafts (FVFG).

Case 1

A 4-year-old girl underwent intercalary resection of the humerus near the humeral head for Ewing sarcoma of the left humerus. The 10.9-cm-long excised bone was frozen in liquid nitrogen for 20 minutes, thawed at room temperature for 15 minutes, and then thawed in distilled water for 10 minutes. Seven months after surgery, the patient fell, and plain radiographs revealed autograft fracture and plate breakage (Fig. 1). Rescue surgery was performed

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Fig. 1. Despite intercalary resection and autograft reconstruction having been performed, autograft fracture and fixation plate breakage occurred after a fall (case 1).

using FVFG. Both the autograft and plate were removed, leaving an 8-cm-long defect. An FVFG was obtained from the ipsilateral leg. The fibula was osteotomized with two struts (length: 7.2 and 8.2 cm). The peroneal artery was anastomosed to the brachial artery. One peroneal vein was anastomosed to the brachial vein, and another to the cephalic vein. The shorter strut was inserted into the medulla and fixed with a small plate, whereas the longer strut was placed medial to the defect as an onlay graft and fixed with a large plate (Fig. 2). Twenty-nine months after FVFG placement, radiographs and CT revealed complete bone union (Fig. 3). Additionally, the cortical thickness of the fibular graft increased from 1.9 mm to 2.3 mm, and the length of the humerus increased from 19.1 cm to 20.9 cm, resulting in normal growth of the affected limb.[7] The patient had a normal range of elevation of her left arm (Fig. 4).

Case 2

A 30-year-old man presented with a parosteal osteosarcoma of the left humerus. He underwent extensive resection of the intercalary tumor, and reconstruction using a pedicled autograft (length 14.6 cm) that had been treated with liquid nitrogen (pedicle freezing method).[2] Three years later, the patient sustained an autograft fracture when he moved his left arm forward. (**See figure 1, Supplemental Digital Content 1**, which displays case 2: preoperative X-ray photograph showing autograft fracture. **http://links.lww.com/PRSGO/C704**.)

Despite open reduction and internal fixation, bone union had not been achieved 2 months after the injury. Two years after the failed open reduction and internal fixation, salvage surgery was performed using an FVFG obtained from the left leg. The peroneal artery and veins were anastomosed to the brachial artery and veins, respectively. A 16-cm-long FVFG was placed medial to the humerus as an onlay graft. Because there was little bone resorption at the fracture site in the treated bone, which provided continuity with the humeral articulation, minimal bone was removed before FVFG transfer, and iliac bone grafted to fill the defect. On postoperative day 14, wound debridement and irrigation were performed because of wound infection, which subsequently healed uneventfully. Nine months after FVFG placement, an inner plate of autogenous iliac bone was added to a small gap between the distal end of the FVFG and humerus. Fifteen months after FVFG placement, complete bone union between the FVFG and humerus was confirmed, whereas bone union had not been achieved at the fracture site in the humerus. (**See figure 2, Supplemental Digital Content 2,** which displays case 2: postoperative X-ray photograph and CT image. **http://links.lww.com/PRSGO/C705**.)

DISCUSSION

It is essential to address complications associated with autografts because the survival rate of patients with malignant bone tumors has improved.[1,3] Advantages of autografts include durability and the ability to modify them in vivo to achieve bone union.[2] However, nonvascularized autograft reconstruction has some limitations and

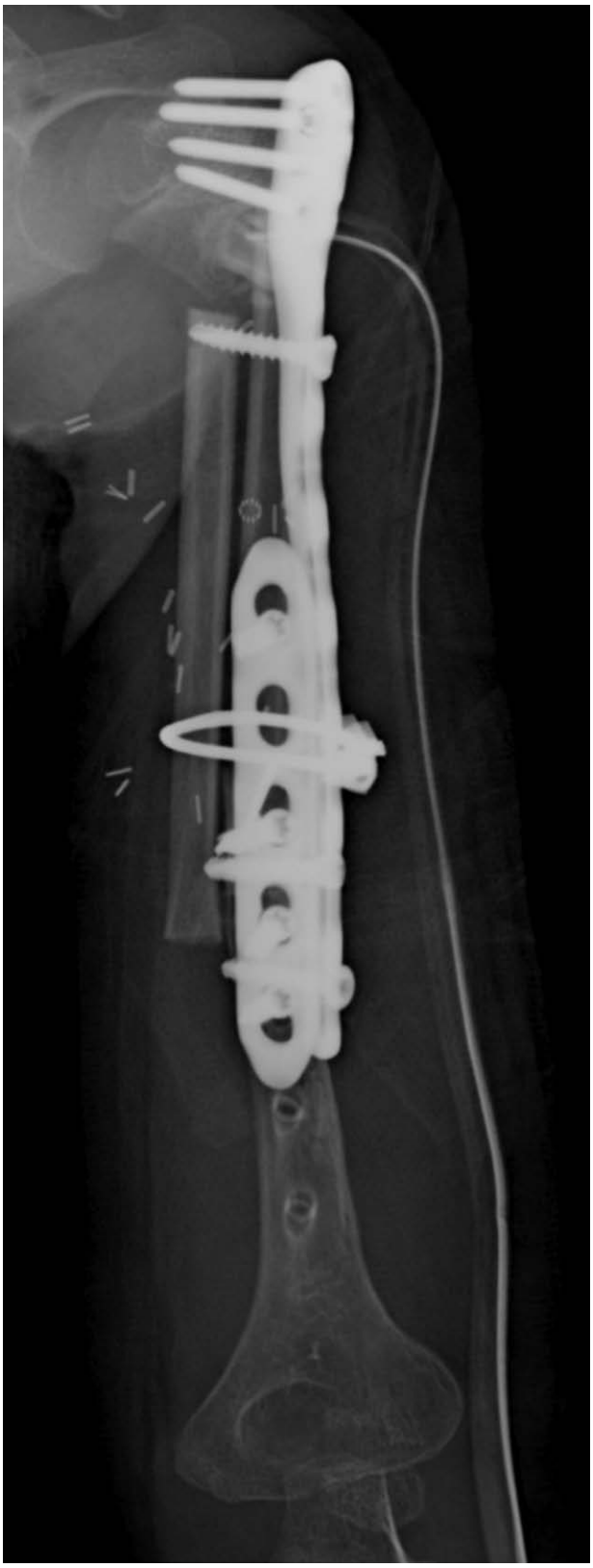

Fig. 2. Double-barreled fibular graft and plates have been fixed with screws and a wire loop (case 1).

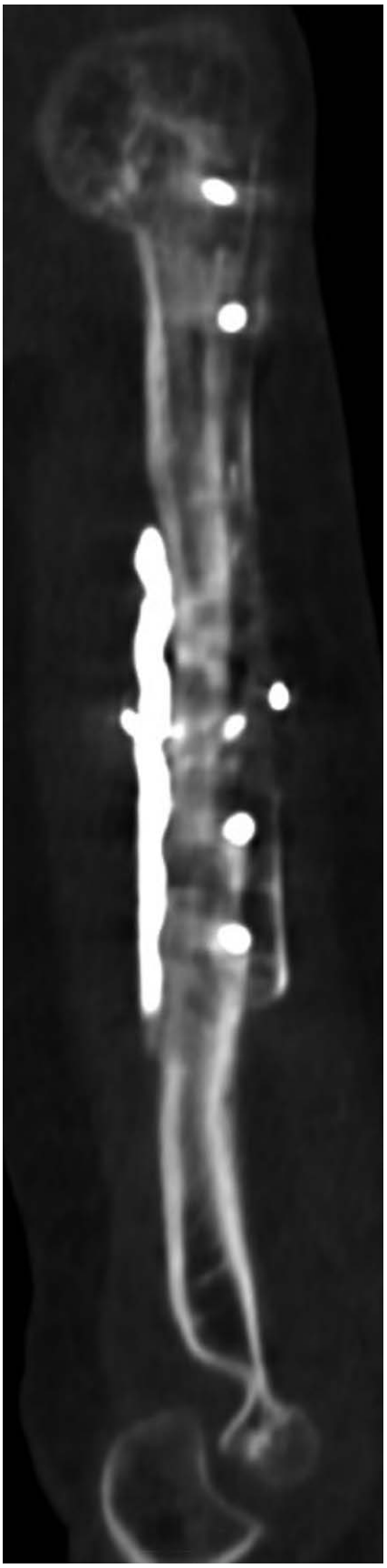

Fig. 3. Case 1: postoperative CT image showing complete bone union.

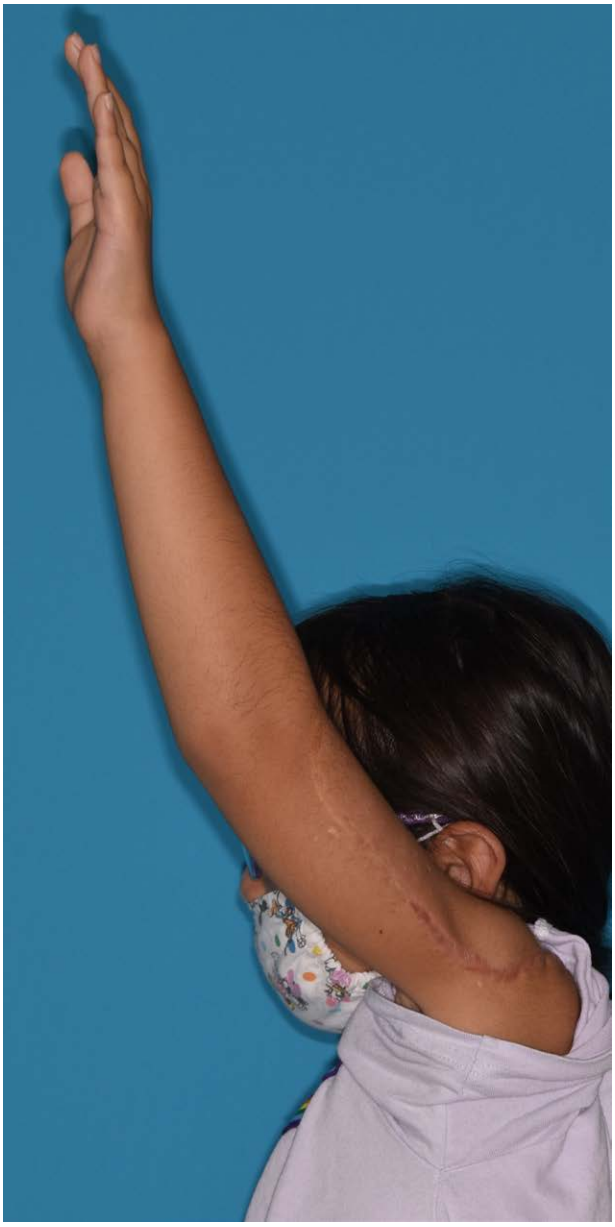

Fig. 4. Case 1: postoperative appearance.

additional possible complications. Previous studies have reported frequent major complications of autografts, including fracture and bone resorption,[4,6] management of which is therefore of paramount importance.

In our cases, refractory humeral fractures after frozen autograft reconstruction were successfully treated with FVFG. Previously reported means of managing fractured autografts have included conservative treatment, open reduction and internal fixation, iliac bone grafting, and prosthesis replacement.[4,5] However, to our knowledge, no one has reported on using FVFG to salvage refractory fractures of autografts. In contrast, FVFGs are already being used to salvage complications of allografts.[8] FVFG placement is also a potential salvage procedure for autograft failure of the humerus.

Two issues are important in the present cases. First, in case 2, the fracture site did not heal despite iliac crest bone grafting, probably because the remnant autograft at the fracture site was not viable enough to support bone union. More extensive debridement and replacement with a fibular flap may have been necessary in this case. Wound infection may also have affected the viability of the iliac crest bone graft. Another important question is whether FVFG should be performed simultaneously with autograft reconstruction. In lower limb reconstruction, liquid nitrogen-treated autografts exhibit a low frequency of bone resorption (0%),[4,6] possibly because bone morphogenetic activity is highly preserved in frozen autografts.[9] In addition, relatively high rates of donor site morbidity of FVFG have been reported in younger individuals.[10] Taken together with the above data, reconstruction with frozen autografts alone may be worth considering for initial reconstruction in the upper limb in teenagers, as in case 1. Primary fibular flap reconstruction may have been preferable in case 2.

CONCLUSIONS

We have reported two cases of refractory fracture of liquid nitrogen-treated autografts in the humerus after tumor resection. FVFGs can be a useful option for salvage of failed autografts.

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DISCLOSURE

The authors have no financial interests to declare in relation to the content of this article.

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