Vascularized fibular grafting for reconstruction of bone defect of the radius

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Background
The vascularized bone graft is indicated in patients where conventional bone grafting has failed or long bone defects, exceeding 6 cm, are observed in the radius. Fibular grafts allow the use of a segment of diaphyseal bone that is structurally similar to the radius and of sufficient length to reconstruct most defects of the radius.
Patients and methods
Between 2005 and 2008, seven patients with segmental bone defects of the radius were managed with vascularized fibular grafts: six females and one male, aged 12 years on average (range, 3–21 years). The length of bone defect was 7.5 cm on average (range, 4–13 cm). In six cases, the fibular graft was harvested as a vascularized osseous flap and in one case, as an osteoseptocutaneous flap. To achieve fixation of the grafted fibula, intramedullary Kirschner wires were used in six cases and plate in one case. The follow-up period ranged from 4 to 39 months.
Results
All flaps were successful. Four patients required secondary procedures in the form of revision of internal fixation, iliac bone grafting, and ulnar shorting. The mean period to radiographic bone union was 4.8 months (range, 2.5–8 months).
Conclusion
Vascularized fibular graft is a reliable technique for reconstruction of bone defects of the radius even in the presence of infection.
Level of evidence
Level IV, therapeutic case series.

Keywords:
bone defect, chronic osteomyelitis of the radius, vascularized fibular graft

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Introduction

Long bone defects (more than 6 cm) of the radius could result from congenital malformations (as congenital pseudoarthrosis), trauma, chronic osteomyelitis, or following resection of locally aggressive or malignant bone tumors. Reconstruction of such long bone defects is one of the most difficult procedures in orthopedic surgery and can be performed using a conventional nonvascularized autograft, allograft, or bone transfer using an Ilizarov external fixator. However, each of these techniques has certain limitations that may compromise the final functional results [1–3].

Vascularized bone grafts remain viable, on the basis of their medullary and periosteal circulation, and heal without creeping substitution as occurs in conventional nonvascularized bone grafts. Thus, direct bony union of the vascularized bone graft to recipient bone is similar to ordinary fracture healing [4]. The iliac crest, rib, and fibula are the best sources for vascularized bone grafts. The fibula is the preferred donor bone for the radius because it is straight, cortical bone and will replace long bone defects. Also, the vascularized fibular graft could be transferred as a composite osteocutaneous or osteomuscular flap when soft tissue cover is needed. In children, the proximal physis of the vascularized fibular graft is available when growth of the graft is needed in the distal radius [5–7].

Patients and methods

Between 2005 and 2008, seven patients with bone defects of the radius were managed with vascularized fibular grafts. There were six females and one male. The mean age of the patients at surgery was 12.5 years (range from 3 to 21 years). The pathology was chronic osteomyelitis in five patients, post-traumatic bone loss in one patient, and aneurysmal bone cyst in one patient (Table 1 and Fig. 1).

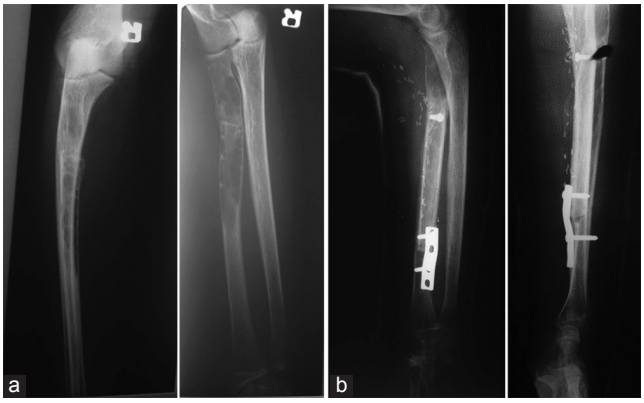
Surgery was performed under general anesthesia with the patient in the supine position and two surgical teams operating consecutively. The recipient site was prepared under tourniquet control by thorough debridement, exposure of the bone ends, and exposure of the recipient vessels (radial artery and superficial

Table 1 Pre-operative data of the patients

Case/sex/age (years)	Site	Pathology	Length of bone defect (cm)	Skin condition at the time of presentation	Infection	Previous operative procedures
1/M/5	Middle third	Chronic osteomyelitis (COM)	6	Multiple sinus draining pus	Yes	Debridement
2/F/14	Upper third	Aeurysmal bone cyst	13	Normal skin	No	None
3/F/3	Middle third	COM	4	A sinus draining pus	Yes	Debridement (twice)Failed nonvascularized fibular graft
4/F/21	Middle third	Postoperative COM	7	A sinus draining pus	Yes	Open reduction and internal fixation (ORIF) of Galeazzi fracturePlate removal and debridement
5/F/16	Distal third	Post-traumatic COM	9	Massive scaring at the distal forearm	Yes	Debridement (3 times) with sequestrectomy
6/F/19	Middle third	Postoperative COM	7	Clean wound	No	ORIF of Galeazzi fracturePlate removal and debridement
7/F/10	Middle third	Post-traumatic bone loss of the radius	7	Raw area (5´3)	Yes	Debridement and temporary fixation by k-wire

F, female; M, male.

Figure 1



Female patient, 14 years old, presented with an aneurysmal bone cyst of the proximal half of the radius. She was treated by local resection and a free vascularized osseous fibular graft. (a) Preoperative radiographs showing the extent of the cyst in the proximal radius. (b) Postoperative radiograph at 3 months, showing full union of the vascularized fibular graft. It had been fixed by a plate and screw.

veins). The mean length of bone defect was 7.5 cm (range from 4 to 13).

Preoperatively, the contralateral leg was carefully evaluated for obvious congenital anomalies, scars, or old fractures. The dorsalis pedis and the posterior tibial pulses were palpable at the ankle in all legs and arteriography was not performed in any patient. In six cases, the fibular graft was harvested as a vascularized osseous flap and in one case as an osteoseptocutaneous flap based on septocutaneous perforators along the posterior crural septum following the technique described by Wei *et al.* [8] and later by Wei and El-Gammal [7]. The fibula was harvested 3–4 cm longer than the length of the bone defect of the radius. In this series, two children required tibiofibular synostosis to maintain the ankle stability of the donor site. In adult patients, the ankle stability was maintained by leaving at least 6 cm from the tip of the lateral malleolus. A split-thickness skin graft was used for coverage of the donor site in the case where the osteoseptocutaneous fibular graft was used. To achieve fixation of the grafted fibula, intramedullary Kirschner wires were used in six cases and plate and screws in one case.

Postoperative monitoring of the osseous fibular flaps in six cases was performed through a small window in the wound. The skin pedal of the osteoseptocutaneous fibular flap in one case was used for monitoring of the circulation.

The mean operative time was 6.5 h (range from 5 to 8) (Table 2). The mean postoperative follow-up period was 19.7 months (range from 4 to 39).

Postoperatively, the patients were managed with low-molecular-weight dextran for 1 week and parenteral antibiotics for 2 days (in case of infection, the administration of antibiotics was continued for 2 weeks). The stitches were removed after 2 weeks.

The follow-up evaluation consisted of clinical and radiographic assessments every month. The radiographic results were either united or not united. Clinical results were rated according to the Tang system as excellent, good, fair, and poor [8,9].

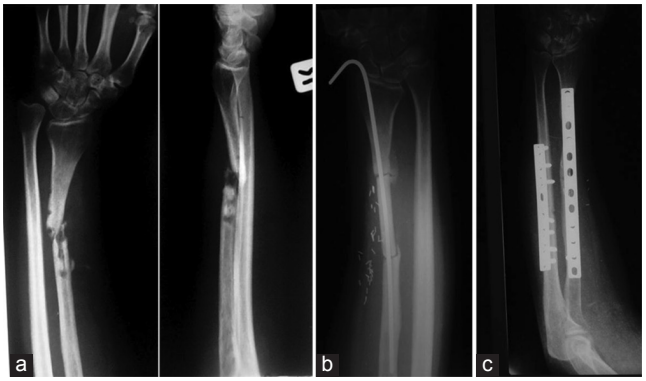
(1) Excellent: ability to carry out normal work.
(2) Good: ability to carry out everyday activities.
(3) Fair: limited ability to carry out everyday activity.
(4) Poor: inability to carry out everyday activity, with either significant limb shortening or pain.

Results

All flaps were successful. The mean follow-up period was 19.7 months (range from 4 to 39). Four patients

required secondary procedures in the form of revision of internal fixation, plate removal, iliac bone grafting, and ulnar shorting. Ulnar shortening was needed in two cases to correct the ulna plus that resulted from shortening of the radius (Fig. 2). All flaps eventually united within an average period of 4.2 months (range from 3 to 9) from the index operation (Table 3). The mean time to union was not affected by the age or sex of the patients, and site and length of the bone defect of the radius. Fibula graft hypertrophy could not be detected in these cases.

Figure 2



Female patient, 22 years old, had a fracture of the shaft right radius. She was treated by ORIF and developed a postoperative infection. The plate was removed 3 months later. She presented with postoperative chronic osteomyelitis of the radius. She was treated by radical debridement and immediate free vascularized osseous fibular graft. (a) Preoperative radiographs showing chronic osteomyelitis of the radius. (b) Postoperative radiograph at 3 months showing delayed union of the vascularized fibular graft that had been fixed by an intramedullary k-wire. She was treated by ORIF by plate and screws together with ulnar shortening at the same time. (c) Postoperative radiograph at 8 months showing full union at both the radius and the ulna.

At the final follow-up, the range of motion of the wrist, elbow, and forearm rotation was measured and compared with the other side. The range of motion of the elbow was normal in all cases. The range of motion of the wrist was normal in four cases and limited in three cases (cases 1, 5, and 7). The forearm rotation was normal in four cases, limited (60% of the other side) in one case (case 1), and stiff in the mid-prone position in two cases (cases 5 and 7). In this study, the clinical evaluation, on the basis of the Tang system, was excellent in four cases and good in two cases. In this series, no donor-site morbidity had occurred.

Discussion

Reconstruction of long bone defects of the radius could be carried out using autograft (conventional nonvascularized or vascularized), allograft, and bone transport using the Ilizarov technique. However, each of these techniques has certain limitations that may compromise the final functional results [1–3].

The use of a nonvascularized bone graft requires a prolonged time of immobilization until complete union. Also, its use is contraindicated in infected, poorly vascularized, and irradiated areas [10,11]. The use of allograft in reconstruction of a bone defect of the radius is only indicated after resection

Table 2 Operative data of the patients

Case	Length of fibula (cm)		Size of skin pedal (cm)	Method of fixation	Anastomosis		Time of (h)	
	Harvested	Used			Radial artery	Superficial vein	Ischemia	Operative
1	9	6	–	K-wires	End to end	One	3	7
2	16	13	–	Plate and screws	End to side	One	2.5	8
3	7	4	–	K-wires	End to end	One	4	6.5
4	10	7	–	K-wires	End to side	One	2	5
5	13	9	7′5	K-wires	End to end	One	2.5	7
6	11	7	–	K-wires	End to end	One	2	6
7	10	7	–	K-wires	End to side	One	2	5.5

Table 3 Reconstructive results of the patients

Case	Time of union (months)	Follow-up duration (months)	Complications		Secondary procedures
			Donor-site	Local	
1	3.5	39	–	–	–
2	3	4	–	–	–
3	3	30	–	–	Ulnar shortening (fixation by plate and screws)Plate removal
4	9	22	–	Delayed union	Internal fixation of the radius by bridge plateUlnar shortening (fixation by plate and screws)
5	4.5	18	–	–	–
6	5.5	15	–	Delayed union	Internal fixation of the radius by bridge plate+iliac bone graft
7	5	10	–	Delayed union	Internal fixation of the radius by bridge plate
Average	4.2	19.7	–	–	–

of a malignant tumor in selected cases and also cannot be used in infected, poorly vascularized, or irradiated areas [12,13]. Bone transport using the Ilizarov technique has limited use in bone defects of the forearm because of the high rate of complications such as pin-track infection, premature consolidation, delayed union at the docking site, and refracture [14–16].

Vascularized bone transfer has most of the prerequisites of the ideal reconstruction of a long bone defect. From the many donor sites available for vascularized bone transfer, the fibula is the preferred donor bone for the radius because it is straight, cortical bone and will replace long bone defects. Also, the vascularized fibular graft can be transferred as a composite osteocutaneous or osteomuscular flap when soft tissue cover is needed. In addition, the peroneal vessels are of sufficient diameter to facilitate the microvascular repairs [5–7].

In this study, all flaps eventually united within an average period of 4.2 months (range from 3 to 9) and this duration was comparable with the previous reports of other authors [8,9,17–19]. There were three cases of delayed union that were fixed primarily by intramedullary Kirschner wires. These cases required revision of internal fixation by a bridge plate to achieve union. Rigid internal fixation was not performed primarily in these cases because of the possibility of recurrence of infection. Fibula graft hypertrophy could not be detected in these cases as the diameter of the fibula matched with that of the radius.

In this series, donor-site morbidity was absent. Tibiofibular synostosis was performed in two patients younger than 10 years of age to prevent the late development of valgus deformity of the ankle in these growing children. The donor-site complications reported are ankle pain, ankle instability, valgus deformity of the ankle, wound infection, gait abnormalities, nerve injuries, and extrinsic flexion deformity of the toes [19–25].

Conclusion

Vascularized fibular graft is a reliable technique for reconstruction of bone defects of the radius even in the presence of infection. A composite fibular graft could solve the soft tissue problem at the same time. Fibular grafts with ensured viability are essential to ensure satisfactory graft union. Refinements of internal fixation techniques result in early union and restoration of function.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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