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Reconstruction of humeral diaphyseal non-unions with vascularized fibular graft

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Objective: The aim of this study was to review the results of 5 diaphyseal non-unions reconstructed using vascularized fibular grafts.

Methods: This study included six non-unions (3 males and 3 females; average age: 47 years; range: 21 to 57 years) reconstructed using vascularized fibular grafts between 2002 and 2007. Average duration of non-union was 59 (range: 12 to 156) months. Fixation was achieved with intramedullary nailing in 3 patients and plates in 3. One case was lost to follow-up at the third postoperative month. The remaining five patients were followed up for an average of 37 (range: 12 to 53) months.

Results: In four cases, union was achieved with a single operation at an average of 4.4 months. A secondary intervention for grafting was required for one patient for inadequate consolidation of the proximal bone-graft interface. Mean radiographic humeral length difference was 3.6 (range: 1 to 7) cm. Average elbow range of motion was 130 (range: 100 to 145), shoulder flexion 167.5 (range: 165 to 170), shoulder abduction 172.5 (range: 170 to 180), internal rotation 75 (range: 70 to 80), and external rotation 92.5 (range: 80 to 100) degrees. Mean DASH score was 10 (range: 5 to 19). According to the Tang system, 3 patients had excellent and 2 good clinical evaluations. Radiologic evaluation revealed four excellent and one fair result. No donor site morbidity was detected.

Conclusion: Our results suggest that vascularized fibular grafting is an effective treatment option for the reconstruction of humeral diaphyseal non-unions.

Key words: Diaphysis; fibula; humerus; non-union.

Despite the progress achieved in the treatment of humeral diaphyseal fractures, non-union is still a major problem. Non-union rates range from 2% to 10% for conservative management and up to 15% for surgical treatment.[1-5] The common characteristics of non-unions at referral are a history of numerous operations and multiple unsuccessful fixations, bone atrophy, segmental loss with scarred and hypovascular surrounding soft tissue and frequently local active infection.[3,6,7]

The introduction of free fibular grafts in the reconstruction of segmental diaphyseal defects of tubular bones has seen an increase in the achievement of a solid union and a functional extremity.

The aim of this study was to review 5 cases of recalcitrant humeral non-union treated using free vascularized fibular grafts.

Patients and methods

Six patients with post traumatic humeral diaphyseal non-unions were reconstructed using free vascularized fibular grafts between 2002 and 2007. The etiology was gunshot wound in one, fall in three and traffic accident

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in two patients. The average age of the 3 male and 3 female patients was 47 (range: 21 to 57) years. Mean non-union time was 59 (range: 12 to 156) months. All patients had previously undergone one to three surgeries for union. All non-unions were manifest at physical and radiologic examination.

A medial approach was used in all cases for bone reconstruction and vascular anastomosis. The brachial artery, its venae comitantes and the median and musculocutaneous nerves were identified and protected throughout the operation. All non-viable bone segments were debrided from both ends of the humeral diaphysis.

A long fibular graft was then harvested from the peroneal artery and its accompanying veins using the technique described by Weiland et al.[8] The distal 8 cm and proximal 4 cm of the fibula was preserved to prevent instability of the knee and ankle joints.

The fibular graft was applied to the humerus in two ways. The double-barrel technique was used in cases with a total circumferential loss of the cortical bone. A trough was fashioned in the medial aspect of the humeral cortex and the graft placed in it in cases with a partial cortical defect. The fibula was fixed to the humerus with one screw at each end.[9] A small amount of autologous cancellous bone was placed around the proximal and distal junctions (Figs. 1 and 2).

Fixation was performed with bridge plates in three patients and intramedullary fixation in the other three. Arterial anastomoses were made end-to-side to the deep brachial artery and at least two venous anastomoses were performed end-to-end to the concomitant veins.

Skin flaps were not used for soft tissue reconstruction in any of our cases. An above-elbow cast-brace was applied for 6 weeks postoperatively. Physiotherapy was initialized at the end of the fourth postoperative week and an arm sling applied until bony union was detected.

Follow-up protocol included repetitive Doppler ultrasonography to evaluate the patency of the anastomosis in the first postoperative week.

The functional elbow results of the operated extremity were evaluated using the Mayo Elbow Performance Index (MEPI), and shoulder results using the Constant-

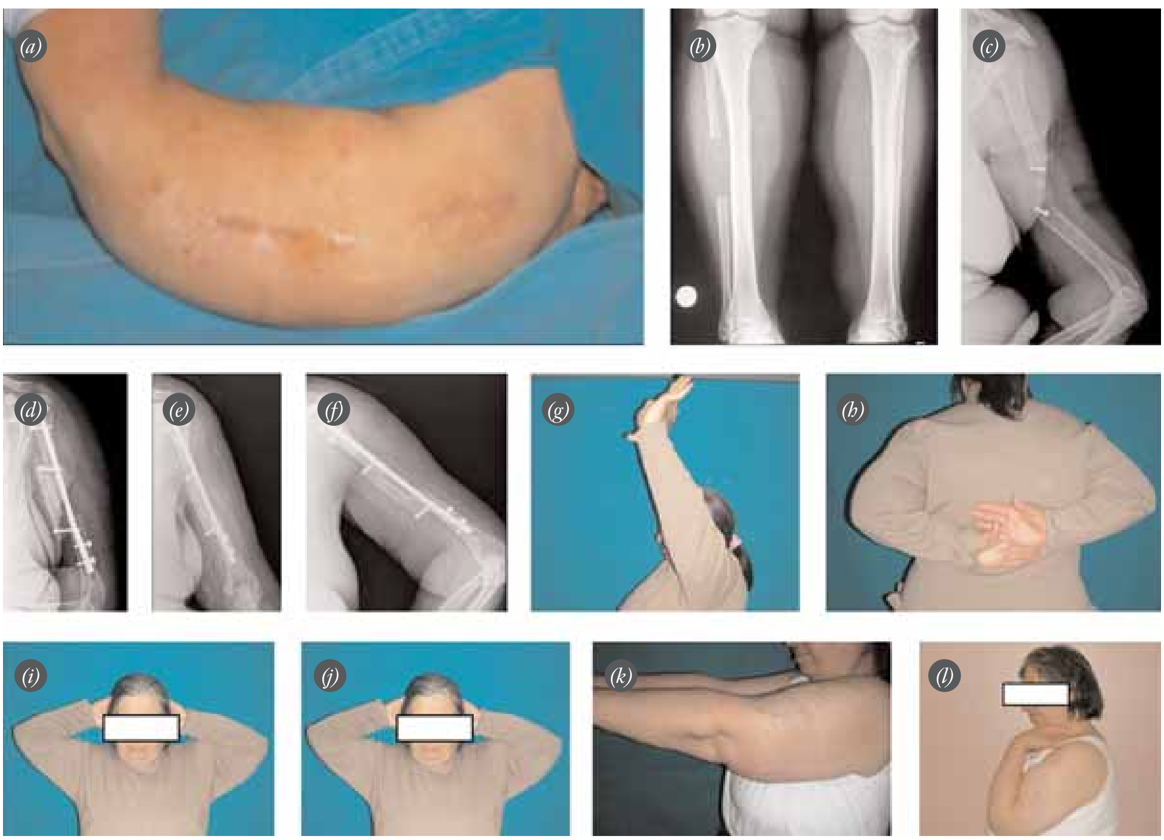

Fig. 1. A 51-year-old-female with a history of nonunion for 36 months and 3 operations (including a non-vascularized fibular application). Preoperative **(a)** view and **(b)** X-ray showing massive resorption of the non-vascularized fibula. After **(c)** intramedullary fixation, **(d)** a double-barreled vascularized fibula fixation was performed. **(e, f)** Union and **(g-l)** functional results afterwards are seen. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Murley Score (CMS). The overall extremity was evaluated using the DASH score and classified according to the Tang system.[10]

Results

One patient was lost to follow-up. Five patients were reviewed for an average of 37 (range: 12 to 53) months from the index operation.

Anteroposterior, lateral and oblique radiographs were obtained at four-week intervals after surgery until bone healing. A secondary operation was required for additional bone grafting of the proximal bone-graft interface in one patient at the eighth postoperative month due to inadequate consolidation. The mean period to radiographic bone union in the remaining 4 cases was 5.2 (range: 4 to 7) months. At the final evaluation, average shortening of the humeri was 3.6 (range: 1 to 7) cm compared to the non-operated side.

Major angular or rotational deformities, malunion, infection or bone absorption or collapse of the fibular graft was not detected in any patients during postoperative follow-up.

The average range of shoulder motion at the final follow-up was 168 degrees of flexion, 172 degrees of

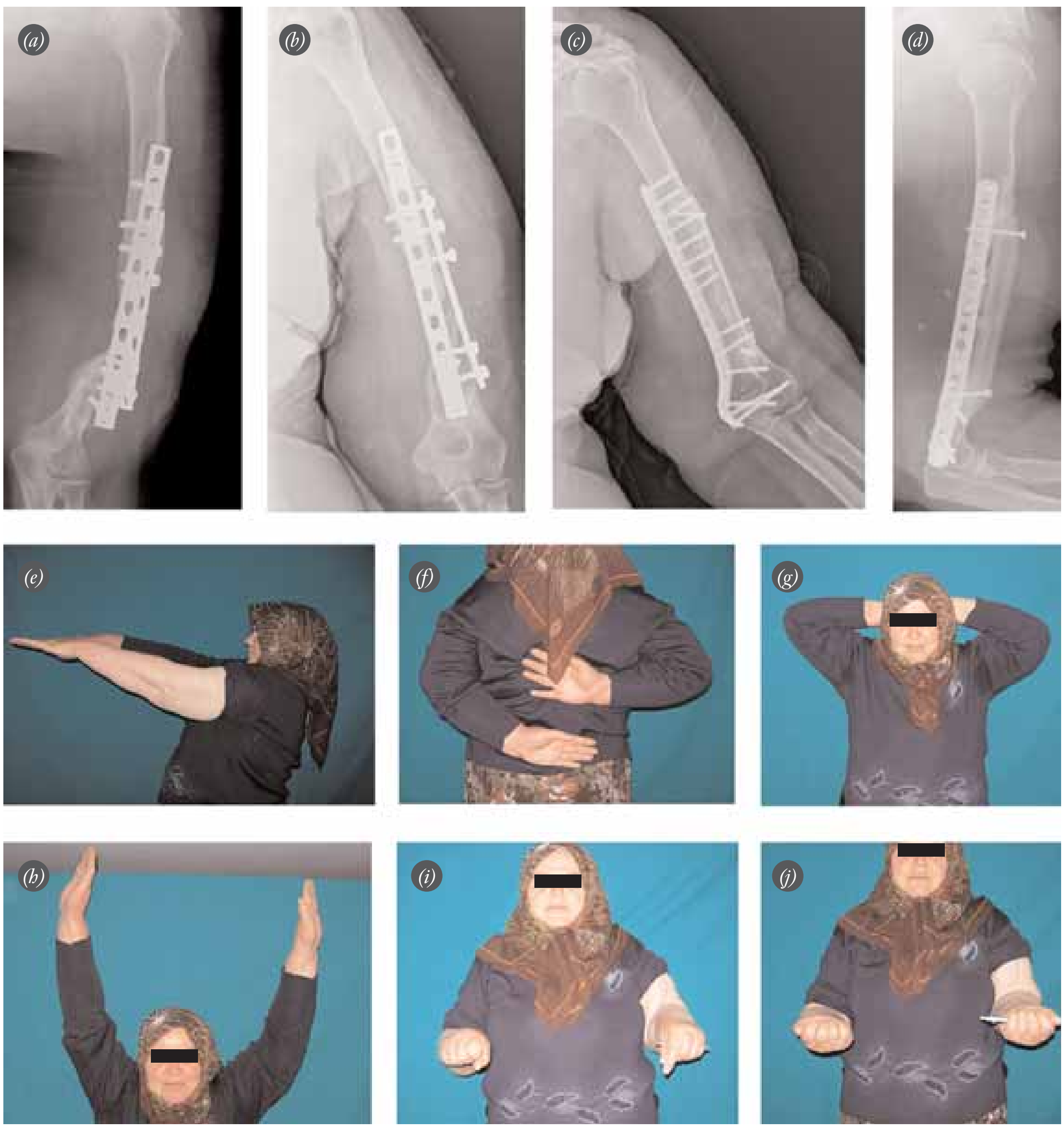

Fig. 2. A 50-year-old female with a history of nonunion for 49 months and 2 operations. Fixation with the **(a, b)** anatomic plate and **(c, d)** fibular graft. **(e-j)** Views from the last examination. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. Functional, clinical and radiological results of the shoulder.

Patient	Flexion (degrees)	Abduction (degrees)	Internal rotation (degrees)	External rotation (degrees)	Constant-Murley Score	Shortening (mm)
1	165	170	70	100	98	72
2	165	170	70	100	90	6
3	170	180	90	90	86	19
4	170	170	90	80	85.7	31
5	170	170	75	80	86	46
Average	**168**	**172**	**75**	**90**	**89**	**34.8**

abduction, 75 degrees of internal rotation and 90 degrees of external rotation. Average CMS was 89 (range: 85.7 to 98) (Table 1).

Total range of elbow flexion and extension was 134 degrees and 6 degrees, respectively, with an average arc of 128 degrees. Mean MEPI was 94 (range: 80 to 100) (Table 2).

According to the Tang system, excellent clinical results was obtained in five patients. The radiologic results were classified as 4 excellent and 1 fair. The patient needing secondary grafting had a fair result, although the bone healed in less than one year.

Discussion

The main issues surrounding atrophic, recalcitrant post-traumatic non-unions of the humerus are altered perfusion of the fracture site and the poor condition of the soft tissues surrounding it, which may be complicated by infection.

Traditional surgical options include intramedullary nailing,[11] compression plating[12] and external fixation,[6] with or without non-vascularized bone graft supplementation. However, these methods do not yield satisfactory results if the recipient site is not well vascularized or if infection is present.[13] In addition, defects longer than 5 to 6 cm in length are not suitable for traditional treatment options.[14,15]

Distraction osteogenesis with bone transfer using the Ilizarov technique seems to be a promising option for established non-unions although its use is currently confined to the treatment of some congenital deformities and specific post traumatic events.[16,17] This technique is not advised for defects exceeding 3 cm on average and is considered more risky for nerve palsy in the upper extremity than in the lower extremity.[18]

Improvements in microsurgical techniques have enabled surgeons to transfer vascularized bone grafts capable of overcoming the classical problems of atrophic non-unions. The survival of such grafts does not depend on the recipient site's vascular and cellular quality.[14] They also increase vascularity at the fracture site which is essential in the promotion of bone healing. The living bone graft supplies osteogenic cells to the fracture, fights infection and enhances the intrinsic stability by permitting simpler and more rapid fracture healing.[19] Vascularized bone also provides a higher biomechanical strength than non-vascularized bone.[13] When appropriate blood perfusion of the flap is restored, the proximal and distal fracture sites have the same healing potential as uncomplicated fractures, with no bone tissue loss or vascular impairment to the central fragment.[1-5]

Among the several donors of vascularized bone grafts reported in the literature,[20,21] the fibula is the leading choice in the treatment of extensive bone defects of the upper extremities based on its favorable structural characteristics, reliable anatomy, and low donor site morbidity.[22-24]

If soft tissue coverage is needed along with a bony reconstruction, a skin paddle can also be added to the bone graft, creating a osteoseptocutaneous fibular transplant.[25,26]

The method of skeletal fixation is based on the unique requirements of the particular defect and the preference of the surgeon. Both intramedullary fixation and bridge plating supply a stable osteosynthesis which can further be strengthened by fixing the fibular graft to both ends of the fracture with cortical screws.[27]

Table 2. Functional and clinical results of the elbow.

Patient	Extension limitation (degrees)	Flexion (degrees)	Mayo Elbow Performance Index
1	0	145	100
2	0	145	100
3	0	130	100
4	20	120	80
5	10	130	90
Average	**6**	**134**	**94**

Once integrated to the recipient site, the fibula is capable of undergoing a remodeling process that can sustain the new functional load. The double-barrel technique, which should be considered for circumferential diaphyseal defects, adds further stability to the construct.[9]

In our study, all patients treated with vascularized fibula graft were able to return to their routine activities and the overall functional results were reasonably good.

Possible complications of this technique are thrombosis of the vascular pedicle, non-union and fracture of the fibular graft. Anastomosis sites should be closely monitored in the early postoperative period. Non-unions are related to weak graft fixation and poor biomechanics, not transplant viability. Fractures of the graft occur due to stress which has a lower risk in the upper extremity than the lower. Marked atherosclerotic disease and a dominant peroneal artery are considered as relative contraindications to this technique.[27]

In conclusion, vascularized fibular graft appears to be an effective treatment option for the reconstruction of humeral diaphyseal non-unions.

Conflicts of Interest: No conflicts declared.

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