ORIGINAL ARTICLE

Acta Orthop Traumatol Turc 2012;46(6):430-437
doi:10.3944/AOTT.2012.2876

Free vascularized fibular grafts in Type 3 open tibia fractures

Kemal ÖZAKSAR, Tahir S. SÜGÜN, Tulgar TOROS, Yusuf GÜRBÜZ, Murat KAYALAR, Fuat ÖZERKAN

Hand Microsurgery Orthopaedics and Traumatology (EMOT) Hospital, İzmir, Turkey

Objective: The aim of this study was to evaluate the results and complications of free vascularized fibular grafting (FVFG) for the reconstruction of bone defects in Gustilo Type 3 open tibia fractures.

Methods: Free vascularized fibular grafting was performed on open tibia fractures with a bone defect of an average of 10 (range: 6 to 18) cm in 21 patients (19 males, 2 females; mean age: 32 years; range: 16 to 47 years). Primary FVFG was performed for 15 patients with open fractures and secondary FVFG in 6 patients with osteomyelitis due to open fractures or defective nonunions. Bony unions were evaluated retrospectively. At a mean follow-up time of 74 (range: 18 to 216) months, 18 patients were examined for malalignment, shortness, and range of motion. Quality of life was evaluated using the Short Form 36 (SF-36).

Results: Mean bony union times for the proximal and distal fibula were 19 (range: 16 to 24) weeks and 20 (range: 16 to 28) weeks, respectively. Proximal nonunion was detected in three patients. Mean external fixation removal time was 6.3 (range: 3 to 14) months. Stress fractures occurred in 15 patients following fixator removal. Malalignment of over 5 degrees was detected in 7 patients and shortness over 2 cm was detected in 4 patients. SF-36 scores were significantly lower in the domains of physical functioning, role limitation due to physical problems, bodily pain, general perception of health, social function, and role limitation due to emotional problems. Mental health, energy and vitality were similar to the healthy reference group.

Conclusion: Free vascularized fibular grafting appears to be a reliable and effective method for reconstructing bone defects and soft tissue defects in a single session in open tibia fractures.

Key words: Free vascularized fibula graft; open fracture; reconstruction.

Gustilo Type 3B and 3C open fractures resulting from high-energy, lower extremity trauma are usually associated with large bone and soft tissue defects; and treatment of these fractures by simple methods results in failure.[1-4] Since the first successful use of a free vascularized fibular grafting (FVFG) for tibial defects by Taylor et al. in 1975, this technique has become standard procedure.[5] FVFG is an effective method of treating bone defects of more than 6 cm following Type 3 open tibial fractures. The advantages of FVFG include the potential for hypertrophy by loading, shorter duration of external fixation compared to bone transport techniques and simultaneous soft tissue coverage whereas its disadvantages are the need for microsurgery, donor site complications and possibility of stress fractures.[6-9]

The aim of this study was to investigate the outcome and complications of FVFG reconstruction of

Correspondence: Tahir S. Sügün, MD. El Mikrocerrahi Ortopedi ve Travmatoloji Hastanesi (EMOT), 1418 Sok. No: 14 35230 Kahramanlar, İzmir, Turkey.

Tel: +90 232 - 441 01 21 e-mail: tssugun@hotmail.com

Submitted: March 29, 2012 **Accepted:** October 8, 2012

Available online at
www.aott.org.tr
doi:10.3944/AOTT.2012.2876
QR (Quick Response) Code:

bone defects following open tibia fractures and to evaluate the quality of life of patients using the Short Form 36 (SF-36).

Patients and methods

FVFG was performed in 21 patients (19 males, 2 females; mean age: 32 years; range: 16 to 47 years) with bone defects of an average of 10 (range: 6 to 18) cm in open tibial fractures between 1993 and 2009. Fifteen patients underwent primary FVFG and 6 underwent secondary FVFG for osteomyelitis or nonunion with a defect after open fractures. The mechanism of injury was traffic accident in 12 patients, heavy construction equipment accident in 5, and gunshot wounds in 4. Mandibular fracture was the only accompanying injury in one patient. According to the Gustilo-Anderson classification, 18 patients had Type 3B and 3 Type 3C open fractures. FVFG was performed at an average of 8 (range: 2 to 40) days after emergency intervention in 15 patients presenting with open fractures and at an average of 35 (range: 4 to144) months in 6 patients with late presentation (Fig. 1). One patient with late presentation had osteomyelitis and 5 had infected nonunions. The patient presenting with osteomyelitis underwent one-stage FVFG, whereas the other patients underwent debridement during the first session and FVFG during the second.

During the operation, a graft 3 cm longer than the defect was taken and placed into the tibial defect. The tibia was divided into three sections in the AP and lateral views. Seven patients had bone defects of the proximal tibia, 6 of the middle tibia and 8 of the distal tibia. The average length of segmental bone defects was 10 (range: 6 to 18) cm. An external fixator was used for fixation in all patients and was performed using 3.5-mm cortical screws proximally in 13 patients and distally in 10 patients. Areas, in which screw fixation was not performed, were placed in the tibial medullary canal.

Six patients underwent repair of the posterior tibial artery. Saphenous vein grafting was performed in three patients, two of which underwent a flow-through of the flap artery to posterior tibial artery (Fig. 1) and one end-to-end anastomosis. Four patients underwent sural nerve grafting and 7 patients additional free flap procedure. Free flaps were performed for revascularization by flow-through of the saphenous venous flap to the posterior tibial artery in one patient, for necrosis of the fibula skin in 2 patients and for widespread soft tissue damage in 4 (Table 1). Anastomoses were performed end-to-end on the tibialis anterior in 3 patients, end-to-side on the tibialis posterior in 2 and end-to-end on the pedicle medial gastrocnemius in one. After the FVFG procedure, a thermoplastic brace was applied to patients in the walking position to prevent equinus deformity and controlled knee and ankle movements were initiated. After fixator removal patients were followed up with braces during hypertrophy of the fibula.

Eighteen patients completing the final follow-up were evaluated at the end of a 74-month (range: 18 to 216 months) follow-up period. The time to union of the fibula was evaluated on radiographs taken on a monthly basis, with the exception of one patient discontinued follow-up at the third month. At the final follow-up examination, range of movement of the knee and ankle joints were measured and radiographs of both the treated and untreated leg were taken. Length and alignment discrepancies between the two legs were measured and compared on the radiographs. The SF-36 was used to evaluate the quality of life of patients.[10-12] This scale is composed of 36 items measuring 8 health related domains, including physical functioning (PF), role limitations due to physical problems (RP), pain (P), general health perception (GHP), mental health (MH), role limitations due to emotional problems (RE), vitality (V), and social functioning (SF). Each item is scored from 0 to 100, with higher scores representing better self-reported health. The data obtained were compared with mean and standard deviation scores for the Turkish population.

Statistical analysis was performed using SPSS 18 software and the comparison of means and standard deviations was used to interpret group data and standards of the general population. A p value of less than 0.05 was considered statistically significant.

Results

A minimum of 18 months of radiological examination was available for all patients with the exception of one. Eighteen patients that attended the final follow-up were evaluated at a mean of 74 (range: 18 to 216) months. The mean bone defect was 10 (range: 6 to 18) cm and the mean length of FVFG was 14 (range: 9 to 20) cm. The dimensions of the skin flap taken with the fibular graft ranged from 3x7 cm to 14x22 cm. Six patients had circulation problems on the skin of the fibula and all of them underwent emergency exploration; anastomoses were renewed due to venous thrombosis in 4 patients and vasospasm in one with no subsequent complication. Vessel patency was normal in the remaining one patient. Two patients had complete and one patient had partial skin necrosis. Latissimus dorsi free tissue transfer was performed in patients with complete necrosis. One of these patients discontinued follow-up at the 3rd month, following resolution of the soft tissue problems.

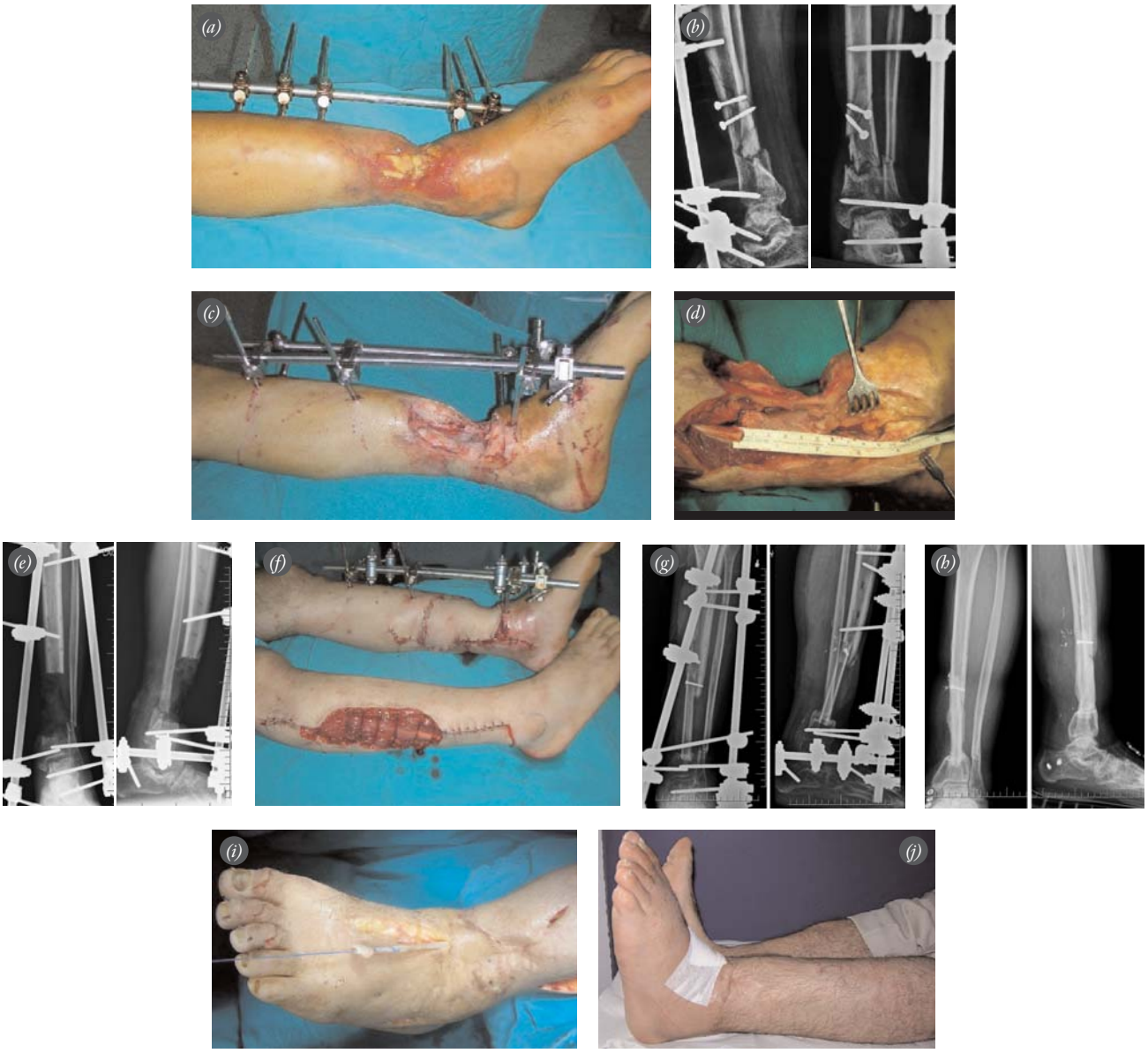

Fig. 1. **(a, b)** The initial views of a late-referred patient (no. 17) on the 4th month after injury with a Type 3B open fracture followed by external fixator application. **(c, d)** The appearance of the posterior tibial artery and nerve with a 9 cm defect created after debridement. **(e)** The appearance of the bone defect after removal of avascular infected bony fragments in the distal tibia. **(f)** The appearance of flow-through free fibular graft after reconstruction of the tibial defect. **(g)** Fifth month postoperative image of the fibula graft showing union. **(h)** Eighteenth month postoperative image of the hypertrophied fibular graft. **(i)** Transfer of peroneus longus tendon to the tibialis anterior tendon to overcome the drop foot. **(j)** Clinical image of the foot after the tendon transfer. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Fracture union was assessed in both the proximal and distal segments of the fibula. The mean duration of union for the proximal and distal fibula was 19 (range: 16 to 24) weeks and 20 (range: 16 to 28) weeks, respectively. The mean time to fixator removal was 6.3 (range: 3 to 14) months. Three patients had nonunion at the proximal fibular graft. After skin grafting at months 8, 11 and 12, bone union was achieved at months 14, 15 and 20. Stress fracture was detected in 15 patients following fixator removal. All patients developing stress fractures were followed up with bracing or casting. Bone union was achieved through casting in 13 patients. An external fixator was applied to 2 patients due deformity developed during the follow-up period.

Range of movement of the knee and ankle joints was significantly decreased compared to the untreated

Table 1. Patients' demographic data with type of fracture, treatment and achieved results.

Pat. no.	Age	Sex	Side	Injury mech-anism	Fracture type	Local-ization	Posterior tibial artery	Tibial nerve	Bone defect (cm)	Follow-up (months)	Fibular cutaneous flap dimension (cm)	Early compli-cation	Early complication treatment	Late complication	Late complication treatment	Time to union (weeks)	
																Proximal	Distal
1	21	M	Left	TA	3B	P	Intact	Intact	12	216	5x11	Infection	Debridement	Stress fracture, shortness 3 cm	Brace	20	24
2	43	M	Left	TA	3B	P	Intact	Intact	11	36	5x12	Infection	Debridement	Stress fracture	Correction with external fixator	16	20
3	28	M	Left	TA	3B	M	Intact	Intact	12	212	4x10	-	-	Stress fracture, 13° varus	Cast	20	20
4	24	M	Left	TA	3B	M	Intact	Intact	11	-	14x22	-	-	Stress fracture, 8° varus, infection	Brace	20	24
5	47	M	Left	HCEA	3B	P	Intact	Intact	8	168	6x20	-	-	Proximal nonunion, 7° varus, shortness 2.5 cm	Bone graft and external fixation. Bony union at 14th month	Nonunion	22
6	31	M	Left	HCEA	3B	P	Intact	Intact	14	164	4x12	Vein thrombosis	Thrombectomy; scapular flap 7x17	Infection, stress fracture	Thrombectomy. Debridement, cast, deformity correction with Ilizarov	20	20
7	34	M	Right	TA	3B	P	Intact	Intact	8	123	8x12	Vein thrombosis	Thrombectomy	Proximal nonunion, stress fracture 10° valgus, shortness 3 cm	Thrombectomy. Bone graft and external fixation. Bony union at 20th month, cast	Nonunion	20
8	30	F	Right	TA	3B	D	Intact	Intact	8	106	8x10	Soft tissue necrosis	Forearm flap	Stress fracture	Cast	20	20
9	47	M	Left	TA	3B	M	Intact	Intact	18	-	7x20	Fibula necrosis	Latissimus dorsi 8x19	Lost	Lost	-	-
10	16	M	Right	TA	3C	D	End-to-end anastomosis	Intact	10	36	7x23	Soft tissue necrosis	Anterolateral thigh flap 13x27 cm	Stress fracture	Cast	20	16
11	28	M	Right	HCEA	3B	D	Intact	Graft 9 cm	6	58	5x15	Talus chondral lesion	Ankle arthrodesis	-	-	20	16

Table 1. [*Contunued*] Patients' demographic data with type of fracture, treatment and achieved results.

Pat. no.	Age	Sex	Side	Injury mechanism	Fracture type	Localization	Posterior tibial artery	Tibial nerve	Bone defect (cm)	Follow-up (months)	Fibular cutaneous flap dimension (cm)	Early complication	Early complication treatment	Late complication	Late complication treatment	Time to union (weeks)	
																Proximal	Distal
12	45	M	Left	TA	3B	P	Intact	Intact	11	24	3x7	Infection	Debridement; latissimus dorsi	Infection, stress fracture	Debridement, cast	20	24
13	16	M	Right	GW	3B	D	Intact	Intact	8	27	3x15	Fibula skin necrosis	Latissimus dorsi 8x17	Infection, stress fracture, 18° valgus, shortness 3.5 cm	Debridement, cast	16	16
14	46	M	Left	TA	3B	M	Vein graft 15 cm	Intact	9	25	6x12	-	-	Proximal nonunion, stress fracture	Bone graft, cast	Nonunion	20
15	31	M	Left	TA	3C	M	Vein graft 5 cm	Graft 4 cm	9	35	5x13	Venous insufficiency	Re-anastomosis	Equinus, intrinsic contracture, stress fracture	Achilles tenotomy, flexor tenotomy of the fingers, cast	16	22
16	44	F	Left	TA	3B	D	Intact	Intact	9	20	5x14	-	-	Donor leg FHL contracture, stress fracture, 10° valgus	Cast	20	20
17	37	M	Left	HCEA	3B	D	Flow-through fibular flap	Graft 9 cm	9	26	8x10	-	-	Intrinsic contracture, drop foot, stress fracture	Flexor tenotomy of the fingers, tendon transfer, cast	16	20
18	18	M	Left	GW	3B	M	Intact	Intact	13	_	7x20	Vein thrombosis	Thrombectomy	-	-	16	16
19	23	M	Left	GW	3C	D	Flow-through venous flap 13 cm	Graft 6 cm	9	24	5x14	-	-	Ankle arthrosis	On follow-up	20	16
20	47	M	Left	GW	3B	P	Saphenous vein graft 6 cm	Intact	10	22	12x20	Tibial plateau defect	Knee arthrodesis	-	-	20	20
21	28	M	Left	HCEA	3B	D	Intact	Intact	6	18	6x16	_	_	Stress fracture, 9° valgus	Cast	22	28

(Sex) M: male, F: female. (Injury mechanism) TA: traffic accident, HCEA: heavy construction equipment accident, G: gunshot wound. (Fracture localization) P: proximal, M: middle, D: distal

leg with ankle movement the more limited (Table 2). Four of 18 patients had limb shortness of over 2 cm with a maximum limb shortness of 3.5 cm. Seven patients had malalignment of greater than 5 degrees. Malalignment was in the valgus direction in 5 patients and the varus direction in 2. The most common late complication was stress fracture, followed by malalignment and other complications. The management of complications is described in Table 1. Following treatment, 6 patients returned to their previous jobs, 7 patients changed jobs and 3 were obliged to retire because of the injury. Two housewives continued their daily activities without hindrance.

The SF-36 scores for PF, RP, P, GHP, SF, and RE were statistically significantly lower than the mean score for the general population. There were no significant differences in MH and V values (Table 3).

Discussion

The treatment of bone and soft tissue defects following Gustilo Type 3 open fractures is challenging. One technique employed is limb lengthening after acute shortening using an external fixator, and complications can be resolved by microsurgery.[13,14] With improvements in microsurgical techniques, a variety of free tissue transfers are available today; in injuries with combined bone and soft tissue defects, vascularized fibular flap is a good option for the reconstruction of both defects.[4,6,15] FVFG offers certain advantages for bone repair as it involves viable bone tissue due to blood flow and, unlike avascular grafts, does not require a revascularization process. Thus, FVFG is more resistant to mechanical loading and can comply with the mechanical properties of the area it is applied to by developing graft hypertrophy.[16,17]

Long-segment bone defects in which avascular grafting techniques failed are the indication for vascularized bone grafting. In addition to primary soft tissue reconstruction with latissimus dorsi flaps followed by vascularized bone grafting, bone and soft tissue defects in open tibial fractures can be restored using vascularized fibular grafting in one session. With its artery supplying the bone, vascularized fibular grafts enable the transfer of viable bone cells, achieve faster bone union compared to avascular grafts and can be performed in the presence of chronic infection.[8,18,19]

Previous studies on FVFG patients have reported union times of 3 to 7 months and union rates of union 75% and 100%.[6,9,20,21] In our series, the time to union was 5 months. After FVFG, 17 of 20 patients achieved union and 3 patients required additional procedure due to proximal nonunion.

Stress fractures following fibular graft harvesting are a common complication and have been reported to occur in 7% to 35% of cases.[9,20,22,23] Stress fractures are

Table 2. Comparison of joint ROMs and tibial lengths.

	Operated side (mean±SD)	Non-operated side (mean±SD)	P
Knee ROM (degrees)	114.5±10.6	125.5±6.4	0.002
Ankle ROM (degrees)	14.2±10.5	51.8±3.8	0.000
Radiologic tibial lengths (cm)	37.7±2.8	39.1±2.6	0.005

Table 3. Comparison of SF-36 sub-dimension scores with population standards (Indifferent values between patient and population scores are written in bold).

SF-36 sub-dimensions	Patients' scores (mean±SD)	Turkish population's scores (mean±SD)	P
Physical function	58.57±23.0	83.8±20.0	<0.0001
Limitation of physical function	50.00±35.5	86.3±24.9	<0.0001
Pain	57.89±20.2	82.9±18.9	<0.0001
General health perception	62.58±30.1	71.6±16.1	0.046
Mental health	**67.71±24.1**	**71.0±24.1**	**0.27**
Limitation of emotion	40.41±41.6	90.1±19.4	<0.0001
Vitality	**62.50±18.9**	**64.5±12.9**	**0.56**
Social function	75.89±28.3	91.0±12.9	<0.0001

less common in double-barrel fibular grafts and were observed in 35% of tibias in a series by Boer and Wood[22] and in 33% of a 46 patient series by Lee and Park.[20] Stress fractures were observed in 15 (75%) of 20 patients with follow-up data in our series. The majority of stress fractures occur during the first year and are attributed to insufficient use of assistive devices, such as braces and crutches during hypertrophy of the fibula following external fixator removal. In addition, alignment of the anatomic fibular graft, stability of the recipient site or fixation of the fracture and posterior cortex continuity of the tibia all reduce the load on the fibular graft and decrease the rate of fracture.[20]

Flap necrosis may be caused by deep infection or venous thrombosis. Arterial and venous anastomotic sites at the site of injury increase the risk of thrombosis. However, when the anastomosed vessels do not function properly, diffuse osteomyelitis or resorption in the fibular graft can occur. Therefore, infected or avascular fibular grafts should be removed from the body during the early period in order to prevent an increase in patient morbidity.[24] In this study, two patients had complete and one patient had partial skin necrosis. Two patients with complete skin necrosis underwent free latissimus dorsi flap coverage after excision of necrotic tissues. One patient discontinued follow-up and the other patient had no complaint of nonunion.

In these types of injuries, the success of treatment modalities is evaluated by the long-term effects on daily activities and quality of life. There are few studies addressing quality of life for this type of complex injury.[25,26] Although our patients' physical and social function, emotional status and pain level were significantly lower than the standards of the general population, which is consistent with the literature, there were no significant differences in mental health and vitality. It is possible that the absence of a significant difference in vitality can be attributed to the patients' effort to pretend to be better than in reality.

In conclusion, FVFG appears to be an effective technique for the treatment of large bone defects combined with soft tissue defects following Type 3 open tibial fractures, due to its ability to manage both problems in one session. However, a high rate of complications is observed. High-energy traumas have negative effects on the quality of life of patients despite the preservation of the extremity.

Conflicts of Interest: No conflicts declared.

References

1. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. J Trauma 1984;24:742-6.
2. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. Plast Reconstr Surg 1986;78:285-92.
3. Beris AE, Lykissas MG, Korompilias AV, Vekris MD, Mitsionis GI, Malizos KN, et al. Vascularized fibula transfer for lower limb reconstruction. Microsurgery 2011;31:205-11.
4. Weiland AJ, Moore JR, Daniel RK. Vascularized bone autografts. Experience with 41 cases. Clin Orthop Relat Res 1983;(174):87-95.
5. Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular technique. Plast Reconstr Surg 1975;55:533-44.
6. Yazar S, Lin CH, Wei FC. One-stage reconstruction of composite bone and soft-tissue defects in traumatic lower extremities. Plast Reconstr Surg 2004;114:1457-66.
7. Tu YK, Yen CY, Yeh WL, Wang IC, Wang KC, Ueng WN. Reconstruction of posttraumatic long bone defect with free vascularized bone graft: good outcome in 48 patients with 6 years' follow-up. Acta Orthop Scand 2001;72:359-64.
8. Han CS, Wood MB, Bishop AT, Cooney WP 3rd. Vascularized bone transfer. J Bone Joint Surg Am 1992;74:1441-9.
9. Arai K, Toh S, Tsubo K, Nishikawa S, Narita S, Miura H. Complications of vascularized fibula graft for reconstruction of long bones. Plast Reconstr Surg 2002;109:2301-6.
10. Ware JE Jr, Shelbourne CD. The MOS 36-item short-form health survey (SF-36). 1. Conceptual framework and item selection. Med Care 1992;30:473-83.
11. Kocyigit H, Aydemir O, Fisek G, Olmez N, Memis A. Validity and reliability of Turkish version of Short form 36: a study of patients with rheumatoid disorder. [Article in Turkish] Journal of Drug and Therapy 1999;12:102-06.
12. Demiral Y, Ergör G, Ünal B, Semin S, Akvardar Y, Kıvırcık B, et al. Normative data and discriminative properties of short form 36 (SF-36) in Turkish urban population. BMC Public Health 2006;6:247.
13. Parmaksizoglu F, Koprulu AS, Unal MB, Cansu E. Early or delayed limb lengthening after acute shortening in the treatment of traumatic below-knee amputations and Gustilo and Anderson type IIIC open tibial fractures: The results of a case series. J Bone Joint Surg Br 2010;92:1563-7.
14. Lee KS, Chung HK, Kim KH. Vascularised osteocutaneous fibular transfer to the tibia. Int Orthop 1991;15:199-203.
15. Kıral A, Arpacıoğlu ÖM, Sarıoğlu A, Kuşkucu M, Rodop O, Kaplan H. Treatment of large segmental bone defects with free, vascularized fibular grafts. [Article in Turkish] Acta Orthop Traumatol Turc 1997;31:216-24.
16. El-Gammal TA, El-Sayed A, Kotb MM. Hypertrophy after free vascularized fibular transfer to the lower limb. Microsurgery 2002;22:367-70.
17. Miniami A, Kasashima T, Iwasaki N, Kato H, Kaneda K. Vascularized fibular grafts. An experience of 102 patients. J Bone Joint Surg Br 2000;82:1022-5.
18. Doi K, Kawakami F, Hiura Y, Oda T, Sakai K, Kawai S. One-stage treatment of infected bone defects of the tibia

with skin loss by free vascularized osteocutaneous grafts. Microsurgery 1995;16:704-12.
19. Yajima H, Kobata Y, Shigematsu K, Kawamura K, Kawate K, Tamai S, et al. Vascularized fibular grafting in the treatment of methicillin-resistant Staphylococcus aureus osteomyelitis and infected nonunion. J Reconstr Microsurg 2004;20:13-20.
20. Lee KS, Park JW. Free vascularized osteocutaneous fibular graft to the tibia. Microsurgery 1999;19:141-7.
21. Zhen P, Hu YY, Luo ZJ, Liu XY, Lu H, Li XS. One-stage treatment and reconstruction of Gustilo Type III open tibial shaft fractures with a vascularized fibular osteoseptocutaneous flap graft. J Orthop Trauma 2010;24:745-51.
22. De Boer HH, Wood MB. Bone changes in the vascularized fibular graft. J Bone Joint Surg Br 1989;71:374-8.
23. Ihara K, Doi K, Yamamato M, Kawai S. Free vascularized fibular grafts for large bone defects in the extremities after tumor excision. J Reconstr Microsurg 1998;14;371-6.
24. Low CK, Pho RW, Kour AK, Satku K, Kumar VP. Infection of vascularized fibular grafts. Clin Orthop Relat Res 1996;(323):163-72.
25. Dagum AB, Best AK, Schemitsch EH, Mahoney JL, Mahomed MN, Blight KR. Salvage after severe lower-extremity trauma: are the outcomes worth the means? Plast Reconstr Surg 1999;103:1212-20.
26. Saddawi-Konefka D, Kim HM, Chung KC. A systematic review of outcomes and complications of reconstruction and amputation for type IIIB and IIIC fractures of the tibia. Plast Reconstr Surg 2008;122:1796-805.