International Orthopaedics (SICOT) (2011) 35:1713–1718
DOI 10.1007/s00264-011-1211-0

ORIGINAL PAPER

Fibula-pro-tibia in plating tibial non-unions

Galal Z. Said · Mohammad M. El-Sharkawi · Hatem G. Said · Omar A. Refai

Received: 12 August 2010 / Accepted: 12 January 2011 / Published online: 12 February 2011

Abstract
Purpose Plating non-unions of the tibial diaphysis often presents the technical problem of poor purchase of screws due to osteoporosis. To improve the stabilization, insertion of one or more screws through the plate across the tibiofibular space to the fibula (fibula-pro-tibia plating) has been practiced. The aim of this study is to evaluate the effectiveness of the fibula-pro-tibia plating technique in managing difficult diaphyseal tibial non-unions.
Methods Between 2000 and 2008, 30 patients with diaphyseal non-union of tibia were managed with this technique. The time between injury and index operation ranged between six and 24 months (average, 11 months). Sixteen patients had three surgical procedures before the index operation, ten had two procedures and four patients had one.
Results The duration of follow-up ranged between ten and 38 months (average 26 months). The mean healing time was 3.5 months. Complications were minimal and included two cases of delayed union which required regrafting after four months and two cases, which had infected nonunion, had reactivation of the infection, which resolved completely after achieving union and removing the plates. There was no negative effect from this fixation technique on the ankle joint motion.
Conclusion The fibula-pro-tibia plating technique is an effective variation in plating diaphyseal tibial non-unions.

G. Z. Said · M. M. El-Sharkawi · H. G. Said · O. A. Refai
Department of Orthopaedic and Trauma Surgery,
Assiut University Hospitals,
Assiut, Egypt

M. M. El-Sharkawi (✉)
Assiut University Medical School,
Assiut, 71511, Egypt
e-mail: sharkoran@hotmail.com

Introduction

Delayed union and non-union are not infrequent complications of surgical treatment of tibial shaft fractures [1, 2]. This is attributed to biological and/or mechanical causes [3]. The most important biological causes are devitalization of bone ends due to high energy trauma or previous surgery, and infection as a complication of open reduction and internal fixation. Mechanical causes of nonunion include the presence of bony defects and inadequate stabilization, due to technical errors or osteoporosis, resulting in poor screw purchase [4].

In 1966, Campanacci and Zanoli coined the term ”fibula-pro-tibia” to express the surgical fibular synostosis they created to treat tibial non-union [4]. Others later also used the same term to express the medial transfer of the fibula (tibialization of the fibula) to treat tibial non-union with large defects [5]. Many published reports also confused the fibula-pro-tibia approach just described and the tibia-pro-fibula screw technique advocated by Panchbhavi et al. who passed two long screws through the fibular plate into the metaphysis of the tibia to enhance stability in osteoporotic ankle fractures [6, 7]. The same technique was also used by others to improve stability in ankle fractures in diabetic patient with good results [8–11].

It has been noticed that the fibular diaphysis, though much smaller than the tibia, is a very strong cortical bone. It holds its strength for a longer duration, even with non weight-bearing. This allows good screw purchase. We made use of this observation by extending the screws from the plate through the tibia and across the tibiofibular space to the fibula (fibula-pro-tibia plating) to salvage tibial nonunion associated with disuse osteoporosis and previous fixation failure. This plate-tibia-fibula construct also constitutes a stable frame of fixation that enhances healing of the non-union.

In this retrospective study, we present our experience in using the fibula-pro-tibia plating technique to increase screw purchase, resistance to pull out and to achieve union.

Material and methods

This study was approved by our institution's ethics committee and all patients gave an informed consent prior to their inclusion in the study. Thirty patients suffering from tibial non-union were surgically treated during the period from January 2000 to June 2008. There were 24 males and six females. Their age ranged between 14 and 72 years (average 42 years). Inclusion criteria were non-union of the tibia associated with osteoporosis, in the diaphyseal area or distal third of the tibia with a small distal fragment. Exclusion criteria were non-union of tibia with good bone stock, active infection, or large bony defects necessitating vascularized fibular graft or bone transport. The duration between the injury and the index procedure ranged between six and 24 months (average, 11 months). The original fracture was open in 20 cases. Sixteen patients had three surgical procedures before the index operation, ten had two procedures and four patients had one. Previous surgeries included soft tissue management by debridement and local or free flaps, internal or external fixation, iliac bone grafting and debridement and hardware removal for infection.

Radiological examination revealed atrophic non-union in 20 cases, non-union with small bony defect in six cases, and hypertrophic non-union in four cases. The level of the tibial fracture was in the middle third in 12 cases, junction of middle and lower third in 12 cases and segmental in six cases. The fibula was intact in three patients, united in one, malunited in five and ununited in 21 patients. The distal segment of the tibia was the seat of osteoporosis while the fibula was of much better bone quality in all patients. Twenty patients had loose or broken plates and screws from previous surgery. Table 1 summarizes clinical data of our patients.

Index surgery included removal of any hardware from previous surgeries, excision of scar tissue and decortication of the tibia. Internal fixation of the tibia was performed by broad DCP in 25 cases, pre-contoured plate in four cases and narrow DCP in a 14-year-old patient. Fibula-pro-tibia screws were inserted through the plate in the distal tibial segment in all cases (one screw in 13 cases, two in six cases, and three in 11 cases). Fibula-pro-tibia screws were also inserted in the proximal segment of the tibia in four cases. After reducing the fracture, the plate is provisionally fixed to both fragments. With the aid of a finger put on the skin opposite the fibula and the drill bit directed about 30 degrees posteriorly, one can target the fibula. Before placing the fibula-pro-tibia screws, care is taken to put the ankle in the maximum attainable dorsiflexion, not to narrow the ankle mortise and cause any further limitation of the ankle motion. Corticocancellous iliac bone graft was inserted at the nonunion site in 26 cases. Non-weight bearing was instituted until union was achieved. Three illustrative cases are shown in Figs. 1, 2, and 3. The outcome parameters were time to union and range of motion at the ankle joint. The presence of bridging callus across the bone fragments in at least three cortices in anteroposterior, lateral, and oblique views, and absence of any metal failure or loosening together with restoration of painless full weight bearing were considered sure signs of achieving solid union. The duration of follow-up ranged between ten and 38 months (average 26 months).

Results

Twenty-two patients showed union at three months' follow-up. Of the remaining patients, four united in four months, and two united in six months. Two patients showing no radiological signs of healing at four months' follow-up were bone grafted, and united two months later. The mean healing time was 3.5 months. Two patients, who had previously infected non-union, had a discharging sinus that did not prevent healing but necessitated plate removal after healing.

At final follow-up, the motion of the ankle dorsiflexion ranged from 0 to 30° in 12 patients, 0–20° in eight patients, and 0–10° in six patients. Four patients had equinus deformity before the index operation, which needed surgical correction. Planter flexion ranged from 0–40° in 25 cases and 0–30° in five cases. The ankle joint did not show arthritic changes in any case. There were no neuro-vascular complications associated with crossing of the tibio-fibular space by the screws.

Discussion

Surgical treatment of fractures of the tibia sometimes results in delayed union and non-union. These complications are more frequently met with after nailing than after plating [1]. Ilizarov techniques gave good results in tibial nonunion, malunion and infection [12]. Free vascularised bone graft is reported to have acceptable healing rates [13–15]; however, it is done in specialized centres and has many complications [16, 17]. Tibiofibular synostosis was also practiced to treat delayed and complex tibial fractures [4, 18].

In protracted cases of non-union of the tibia the bone is the seat of osteoporosis, especially the distal segment. This often presents a problem in plate and screw fixation, especially so if the distal segment is small. To increase the hold of screws in osteoporotic bone, injectable bone

Table 1 Clinical data of 30 patients

Serial number	Gender	Age	Accident-index surgery (interval in months)	Skin condition	Number of previous operations	Type of non- union	Level of tibial fracture	Fibula	Type of plate used	Fibula-pro-tibia screws	Bone graft
1	M	22	11	IC	2	Atrophic	M/L 1/3	Non-union	Broad DCP	2 in distal fragment	+
2	M	46	12	IC	3	Atrophic	Segmental	Intact	Broad DCP	3 in distal fragment	+
3	M	42	13	IOII	3	Defect	L 1/3	Non-union	Pre-contoured	1 in distal fragment	+
4	F	62	10	IC	2	Atrophic	M/L 1/3	Non-union	Broad DCP	1 in distal fragment	+
5	M	58	16	IOIII	3	Defect	L 1/3	Non-union	Broad DCP	1 in distal fragment	+
6	M	33	9	IOIII	1	Hypertrophic	L 1/3	Non-union	Broad DCP	1 in distal fragment	-
7	M	25	10	IOIII	2	Atrophic	Segmental	Mal-union	Broad DCP	2 in distal fragment + 1 in proximal fragment	+
8	M	72	9	IOIII	3	Atrophic	M/L 1/3	Non-union	Broad DCP	1 in distal fragment	+
9	F	44	13	IOII	3	Atrophic	L 1/3	Non-union	Broad DCP	1 in distal fragment	+
10	M	42	24	IOIII	2	Defect	L 1/3	Non-union	Broad DCP	3 in distal fragment	+
11	M	37	11	IOIII	3	Atrophic	Segmental	Non-union	Pre-contoured	2 in distal fragment + 3 in proximal fragment	+
12	M	38	10	IOII	2	Hypertrophic	M/L 1/3	Mal-union	Broad DCP	3 in distal fragment	-
13	M	64	17	IC	3	Atrophic	L 1/3	Non-union	Broad DCP	1 in distal fragment	+
14	M	59	17	IC	3	Atrophic	Segmental	Non-union	Broad DCP	3 in distal fragment + 1 in proximal fragment	+
15	M	50	15	IOIII	2	Atrophic	M/L 1/3	Non-union	Broad DCP	2 in distal fragment	+
16	F	40	8	IOIII	3	Atrophic	L 1/3	Non-union	Broad DCP	1 in distal fragment	+
17	M	27	10	IOIII	2	Atrophic	L 1/3	Intact	Broad DCP	1 in distal fragment	+
18	M	26	13	IOII	3	Atrophic	M/L 1/3	Non-union	Broad DCP	1 in distal fragment	+
19	M	45	6	IOIII	2	Defect	L 1/3	Mal-union	Pre-contoured	3 in distal fragment	+
20	F	38	9	IC	3	Atrophic	M/L 1/3	Mal-union	Broad DCP	1 in distal fragment	+
21	M	53	6	IOII	1	Atrophic	L 1/3	Union	Broad DCP	3 in distal fragment	+
22	M	42	8	IOIII	3	Hypertrophic	M/L 1/3	Mal-union	Broad DCP	1 in distal fragment	-
23	F	44	11	IC	2	Atrophic	M/L 1/3	Non-union	Broad DCP	3 in distal fragment	+
24	M	14	15	IOIII	3	Defect	L 1/3	Non-union	Narrow DCP	1 in distal fragment	+
25	M	56	7	IOIII	1	Atrophic	Segmental	Non-union	Broad DCP	2 in distal fragment + 2 in proximal fragment	+
26	M	47	6	IC	2	Atrophic	M/L 1/3	Non-union	Broad DCP	3 in distal fragment	+
27	M	28	12	IOIII	3	Atrophic	L 1/3	Intact	Pre-contoured	1 in distal fragment	+
28	M	22	7	IOIII	3	Defect	M/L 1/3	Non-union	Broad DCP	3 in distal fragment	+
29	M	26	7	IOIII	3	Atrophic	Segmental	Mal-union	Broad DCP	3 in distal fragment	+
30	M	62	8	IC	1	Hypertrophic	M/L 1/3	Non-union	Broad DCP	2 in distal fragment	-

M male, *F* female, *DCP* dynamic compression plate

Fig. 1 A 37-year-old male patient (case 11) had had an open III segmental fracture of the tibia that was unsuccessfully treated by intramedullary nailing, which was revised by plating and then got infected. **a** After the first stage of hardware removal and debridement. **b** Second stage six weeks later, excision of avascular bone and scar tissue, iliac bone grafting and contoured plate fixation. Three screws were extended into the fibula in the proximal segment and two in the distal segment together with two screws in the bone graft. **c**, **d** Anteroposterior and lateral views show bone healing at 12 months follow-up. The patient has resumed his previous work as a construction worker

cement or bone substitutes were used [3, 7]. Locked plates have also improved the technique of plating in atrophic bone [19]. Fixation of the fibula in addition to the tibia was also recommended, to add to the stability of fixation, especially in distal third, comminuted, unstable tibial fractures and with intramedullary nailing of the tibia [20, 21].

In osteoporotic ankle fractures, passing two screws across the tibiofibular synostosis into the tibial metaphysis in addition

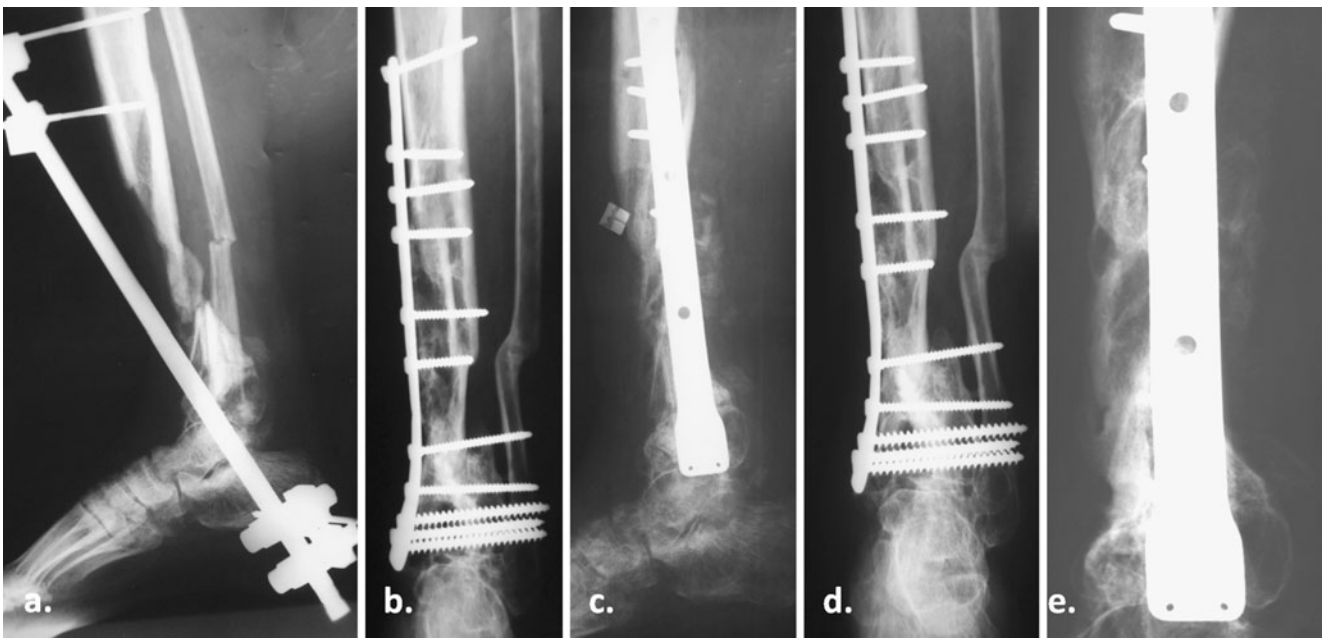

Fig. 2 A 45-year-old farmer (case 19) had had an open III comminuted fracture of the left tibia and fibula. After repeated debridement and temporary external fixator application, soft tissue coverage was performed by a local flap. **a** Lateral plain X-ray shows the nonunion with bone loss, and temporary fixation by an external fixator. **b**, **c** X-rays taken two weeks postoperatively after plating and bone grafting and three screws extended to the fibula. **d**, **e** Two years follow-up X-rays showing complete healing of the fracture

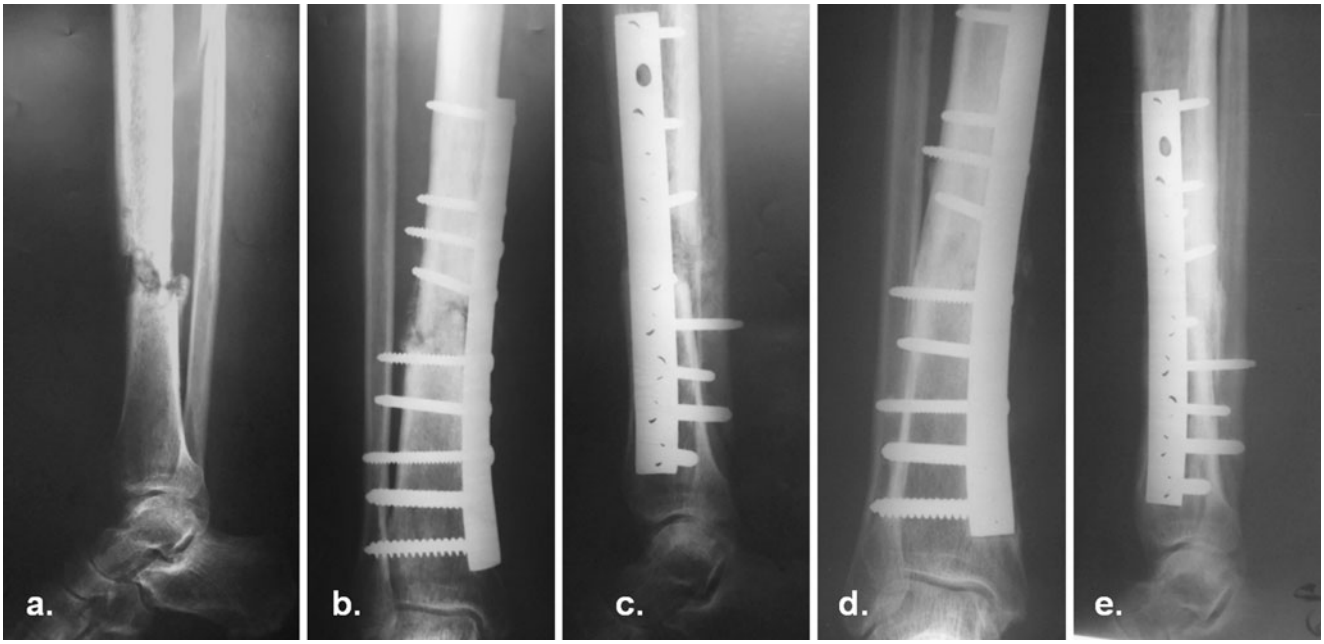

Fig. 3 A 53-year-old farmer (case 21) suffered a tractor accident and had an open II fracture of the tibia (among other injuries) that was treated conservatively in a local hospital by debridement and later on by reduction and above the knee plaster cast. He presented six months later with atrophic ununited tibia. Because he had unhealthy scar tissue just below his knee excluding the possibility of intramedullary nailing, plating and bone grafting was planned for him. Because of severe osteoporosis of the distal segment, three screws were advanced through the distal tibia to the fibula. **a** Preoperative X-ray. **b**, **c** Six weeks follow-up X-ray films show bridging callus. Partial weight bearing was then allowed and increased gradually to full weight bearing during the following six weeks. The patient resumed all his activities four months post-surgery. **d**, **e** Two years follow-up X-ray films show complete remodeling of the fracture

to hook plate fixation gave better results than the classical AO technique as regards to union of the fracture [6, 7]. In diabetic ankle fractures passing screws through a fibular plate to the tibia was also practiced with favourable results [8].

The idea of extending the screws through the plate and tibia, across the tibiofibular space to the fibula (fibula-pro-tibia) for treating diaphyseal tibial non-union is new and has not been published before in the English literature. This fibula-pro-tibia fixation technique, successfully used in this study, adds two more cortices for screws purchase. It significantly increases the pull-out strength of the screws and increases the chance of union. This quadricortical screw purchase has been previously reported to successfully treat non-unions of the humerus [22, 23] and has also been proved biomechanically to significantly increase the pull-out strength of the screws [24].

A major concern of this technique, however, is the immobilization of the distal tibiofibular joint, which might have a negative effect on the overall ankle motion. Care was taken in this series to place the ankle in maximum achievable dorsiflexion before inserting the fibula-pro-tibia screws to avoid any further narrowing of the ankle mortise. The ankle joint, however, was already stiff in many patients with long-standing tibial nonunion, who were subjected to repeated surgeries entailing prolonged swelling and non-weight bearing. We did not observe any further negative clinical effect due to fixation of the inferior tibiofibular joint on the ankle joint movement as was shown by the absence of pain and any appreciable radiological changes. On the contrary, whenever rigid fixation of the fracture is achieved, early mobilization and rehabilitation was started and contributed to good ankle joint movement. Other authors have also reported that lack of distal tibiofibular motion has no significant effect on patient's normal walking ability [25, 26]. Moreover, the hardware can be removed after complete consolidation of the non-union, to reduce the theoretical effect of fixation on the tibiofibular articulation.

Safety of the technique is another major concern. The tibiofibular space has been extensively studied in every level by Catagni et al. [27]. Passing Ilizarov wires from the fibula to the tibia or vice versa was proven to be safe and does not endanger the neurovascular bundle [27]. In our study, passing the drill bit, tap and screws across the tibiofibular space did not cause any clinically detectable damage to the neuro-vascular bundles of the leg. Other authors as well reported no harmful effect from passing screws from fibula to tibia in diabetic ankle fractures [8–11]. A possible technical difficulty in the described technique is targeting the smaller fibula by the drill bit. However, knowing the anatomical fact that the fibula lies posterior to the tibia by

about 30° [27] and directing the drill bit at a finger put on the skin opposite the fibula, facilitates reaching it.

The use of "fibula-pro-tibia plating" as a title to express our technique could be criticized as not adequately describing the technique and falsely implying transporting the fibula to biologically enhance tibial union. However, the selected term is an analogy which has been previously published by many authors describing screws threading in a reverse direction from the fibula to the tibia in osteoporotic and diabetic ankle fractures [6–11]. All these reports have used the tibia only to biomechanically foster screw purchase and achieve fracture healing.

The drawbacks of this study are that there is no comparison with other lines of treatment of non-union of the tibial shaft as every case is unique in regards to the injury, previous treatment and surgical technique. Although nowadays, the use of locked plates might diminish the use of this technique, it remains a good alternative when these special plates are unavailable. The technique of fibula-pro-tibia screw fixation proved to enhance the screw purchase and immobilization of difficult non-unions of the tibia and to facilitate bone union.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Vallier HA, Le TT, Bedi A (2008) Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. J Orthop Trauma 22(5):307–311
2. Said GZ, Farouk O, Said HG (2009) Delayed union of multi-fragmentary diaphyseal fractures after bridge-plate fixation. Int Orthop 33(2):549–553
3. Gardner MJ, Evans JM, Dunbar RP (2009) Failure of fracture plate fixation. J Am Acad Orthop Surg 17(10):647–657
4. Campanacci M, Zanoli S (1966) Double tibiofibular synostosis (fibula pro tibia) for the non union and delayed union of the tibia. J Bone Joint Surg Am 48:44–56
5. Föhn M, Bannasch H, Stark GB (2009) Single step fibula-pro-tibia transfer and soft tissue coverage with free myocutaneous latissimus dorsi flap after extensive osteomyelitis and soft tissue necrosis—a 3 year follow up. J Plast Reconstr Aesthet Surg 62 (11):466–470
6. Panchbhavi VK, Mody MG, Mason WT (2005) Combination of hook plate and tibial pro-fibular screw fixation of osteoporotic fractures: a clinical evaluation of operative strategy. Foot Ankle Int 26(7):510–515
7. Panchbhavi VK (2007) Augmentation of internal fixation of osteoporotic ankle fracture using injectable bone substitute. Foot Ankle Surg 6(4):264–269
8. Schon LC, Marks RM (1995) The management of neuroarthropathic fracture-dislocation in the diabetic patient. Orthop Clin N Am 26(2):375–292
9. Bibbo C, Lin SS, Bean HA, Behrens FF (2001) Complications of ankle fractures in diabetic patients. Orthop Clin N Am 32(1):113–133
10. Prisk VR, Wukich DK (2006) Ankle fractures in diabetics. Foot Ankle Clin 11(4):849–863
11. Perry MD, Taranow WS, Manoli A II, Carr JB (2005) Salvage of failed neuropathic ankle fractures: Use of large fragment fibular plating and multiple syndesmotic screws. J Surg Orthop Adv 14:85–91
12. March DR, Shah S, Elliot J, Kurdy N (1997) The Ilizarov method in nonunion, malunion, infection of fractures. J Bone Joint Surg Br 79:273–279
13. Tu YK, Yen CY, Yeh WL, Wang KC, Ueng WN (2001) Reconstruction of long bone defect with free vascularised bone graft: good outcome in 48 patients with 6 years' follow-up. Acta Orthop Scand 72:359–364
14. Lee KS, Park JW (1999) Free vascularised osteocutaneous fibular graft to the tibia. Microsurgery 19:141–147
15. Takami H, Takahashi S, Andro M, Masuda A (1997) Vascularised fibular grafts for reconstruction of segmental tibial bone defects. Arch Orthop Trauma Surg 116:404–407
16. Arai K, Toh S, Tsubo K, Nishikawa S, Narita S, Miura H (2002) Complications of vascularised fibula graft for reconstruction of long bones. Plast Reconstr Surg 109:2301–2306
17. Malizos KN, Nunley JA, Goldner RD, Urbaniak JR, Harrelson JM (1993) Free vascularised fibula in traumatic long bone defects and limb salvaging following tumor resection: comparative study. Microsurgery 14:368–374
18. Ebraheim NA, Haman SP, Sabry FF, Emara K (2005) Tibiofibular synostosis procedure in the management of complex tibial fractures. Am J Orthop 4:493–497
19. Gardner MJ, Griffith MH, Demetrakopoulos D et al (2006) Hybrid locked plating of osteoporotic fractures of the humerus. J Bone Joint Surg Am 88:1962–1967
20. König M, Gotzen L (1989) Pseudarthroses of the fibula following fracture of the lower leg. Unfallchirurg 92(4):191–194
21. Weise K, Hermichen H, Weller S (1985) Significance of the fibula in tibial fractures and pseudarthrosis. Aktuelle Traumatol 15 (5):195–204
22. Farouk O, El-Sherif E, Mostafa K, Khalil A (2008) Intramedullary fibular graft and quadricortical plate fixation in atrophic non-union of the osteoporotic humerus. Injury 39:152–154
23. Vidyadhara S, Vamsi K, Rao SK, Gnanadoss JJ, Pandian S (2009) Use of intramedullary fibular strut graft: a novel adjunct to plating in the treatment of osteoporotic humeral shaft nonunion. Int Orthop 33(4):1009–1014
24. Wright TW, Miller GJ, Vander Griend RA, Wheeler D, Dell PC (1993) Reconstruction of the humerus with an intramedullary fibular graft. A clinical and biomechanical study. J Bone Joint Surg Br 75(5):804–807
25. DeOrio JK, Ware AW (2003) Salvage technique for treatment of periplafond tibial fractures: The modified fibula-pro-tibia procedure. Foot Ankle Int 24(3):228–232
26. Jend HH, Ney R, Heller M (1985) Evaluation of tibiofibular motion under load conditions by computed tomography. J Orthop Res 3:418–423
27. Catagni MA, Malzev V, Kirienko A (1994) The anatomic location for insertion of wires and half pins. In Maiocchi AB (ed) Advances in Ilizarov apparatus assembly, 1st edition. Medical-plastic SRL, Milan, p 17