International Orthopaedics (SICOT) (1998) 22:293–297

International Orthopaedics

Tibial bone defects treated by internal bone transport using the Ilizarov method

H.-R. Song[1], **S.-H. Cho**[1], **K.-H. Koo**[1], **S.-T. Jeong**[1], **Y.-J. Park**[1], **J.-H. Ko**[2]

[1] Department of Orthopaedic Surgery, School of Medicine, Gyeong-Sang National University, 92 Chilam-dong, Chinju 660-702, Republic of Korea
[2] Department of Orthopaedic Surgery, Choong-Ang Gil Hospital, Incheon, Republic of Korea

Accepted: 7 November 1997

Abstract. *We reviewed 27 cases of tibial bone defects treated by internal bone transport using the Ilizarov method. The causes of the bone defects were open fractures in 14 segments and infected non-unions in 13. The average length of the defects was 8.3 cm (range, 3–20 cm). There were 21 one-level tibial transports, 3 two-level tibial transports, 1 one-level tibial transport with fibular transport, and 2 fibular transports. At the docking site, 25 segments underwent bone grafting. Eleven of the 25 were Papineau-type open cancellous bone grafts. Acute shortening or docking was performed in 10 segments. Bone union was obtained in every instance. The average time of external fixation was 8 months and the average time to union was 7.1 months. Bone grafting at the docking site is recommended in order to shorten the duration of treatment and to prevent refracture and non-union.*

Résumé. *Nous avons passé en revue 27 cas de perte de substance du tibia traités par «transport osseux interne» conformément à la méthode Ilizarov. Ces anormalies provenaient de fractures ouvertes dans 13. La longeur moyenne des defect osseux était de 8,3 cm (entre 3 et 20 cm). On a effectué 21 «transports tibiaux» de niveau 1, 3 «transports tibiaux» de niveau 2, 1 «transport tibial» avec «transport du péroné», ainsi que 2 «transport du péroné». Dans 25 cas une greffe osseuse a été pratiquée sur le site de réduction. 11 cas des 25 greffes pratiquées étaitent du type Papinau. D'importances réduction ont dû étre effectuées dans 10 cas. Des fusions ont été obtenues dans tous les cas. Le temps moyen de fixation externe était de 8 mois et celui de fusion de 7,1 mois. La greffe osseuse est recommandée sur le site de réduction afin de raccourcir la durée du traitement et de prévenir toute récidive de fracture ou de non-consolidation.*

Reprint requests to: H.-R. Song, Department of Orthopaedic Surgery, School of Medicine, Gyeong-Sang National University, 92 Chilam-dong, Chinju 660-702, Republic of Korea

Introduction

Segmental bone defects have been treated by various methods including cancellous bone grafting [7, 10, 11]. Papineau-type open cancellous bone grafting [12, 20, 21, 23, 24] vascularised fibular grafts [2, 25, 28] and internal bone transport with an external fixator [1, 13, 14, 15].

Autologous bone autografting is limited primarily by the quantity which can be harvested from the donor site. While vascularised osseous transfer has been successful in bridging large bone defects in the forearm [27], there are disadvantages in using this method in the lower limb [2, 6, 8, 17, 28]. These problems include length limitations of the transfer, a high incidence of refracture, pseudoarthrosis, and difference in size between the donor site and the graft mass, which could produce a potential stress concentration during weight bearing.

Soft tissue transfixation by the crossed wires used with the Ilizarov apparatus precludes the combination of soft tissue surgical procedures such as free or rotational flaps in the treatment of open fractures [16]. However, a combined procedure is possible using monolateral fixators. The modified Ilizarov system, namely an Ilizarov ring and half-pin fixation, permits certain orthopaedic approaches for associated soft tissue defects. Simultaneous transport of soft tissue and bone with the Ilizarov apparatus has distinct advantages in these circumstances.

The purpose of this study is to evaluate the results and complications of internal bone transport for large bone defects, with or without soft tissue loss, using the Ilizarov method.

Patients and methods

Thirty-one patients with tibial bone defects were treated by internal bone transport using the Ilizarov method between March 1991 and July 1995. Twenty-six patients with 27 segments were available for follow-up. There were 24 males and 2 females with ages ranging from 15 to 63 years (average 42 years). The causes of the bone defects were open fractures in 14 and infected non-unions in 13. The average length of the defects was 8.3 cm (range 3–20 cm). Fourteen segments had open fractures with bone loss ranging from 3 to 20 cm (average 8.3 cm). The open fractures were grade IIIA in 3 patients,

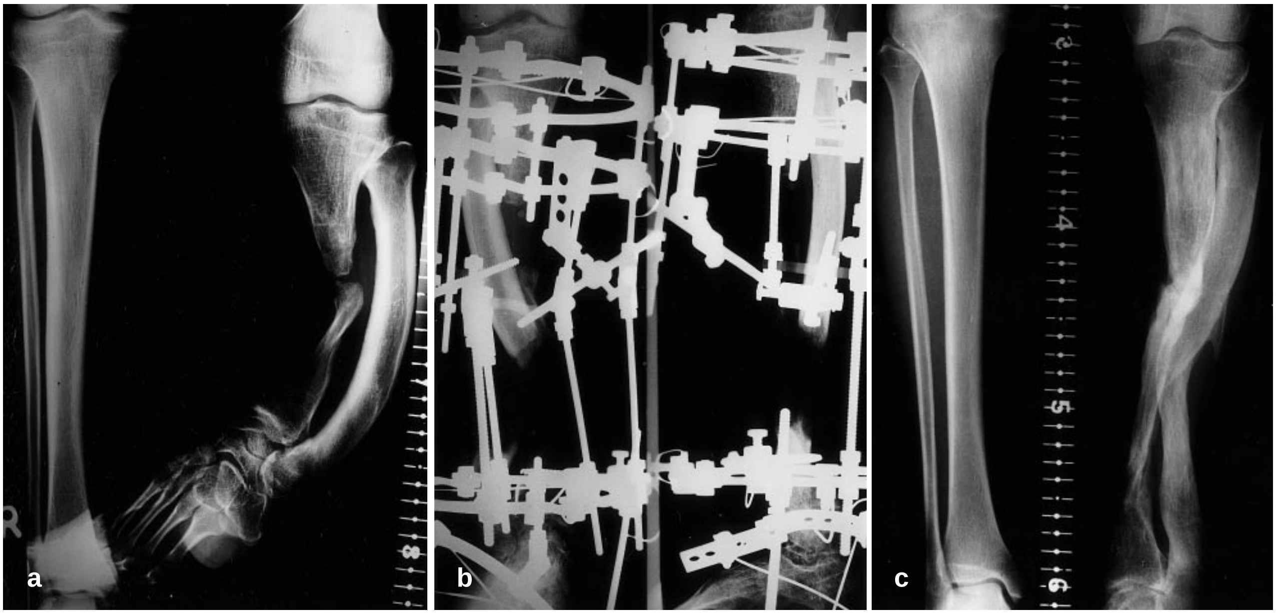

Fig. 1. a Shortening and fibular hypertrophy due to an infected non-union of the left tibia. **b** Proximal tibial corticotomy and distal tibiofibular corticotomy were performed to correct the shortening and the bone defect. **c** Radiograph at final follow-up

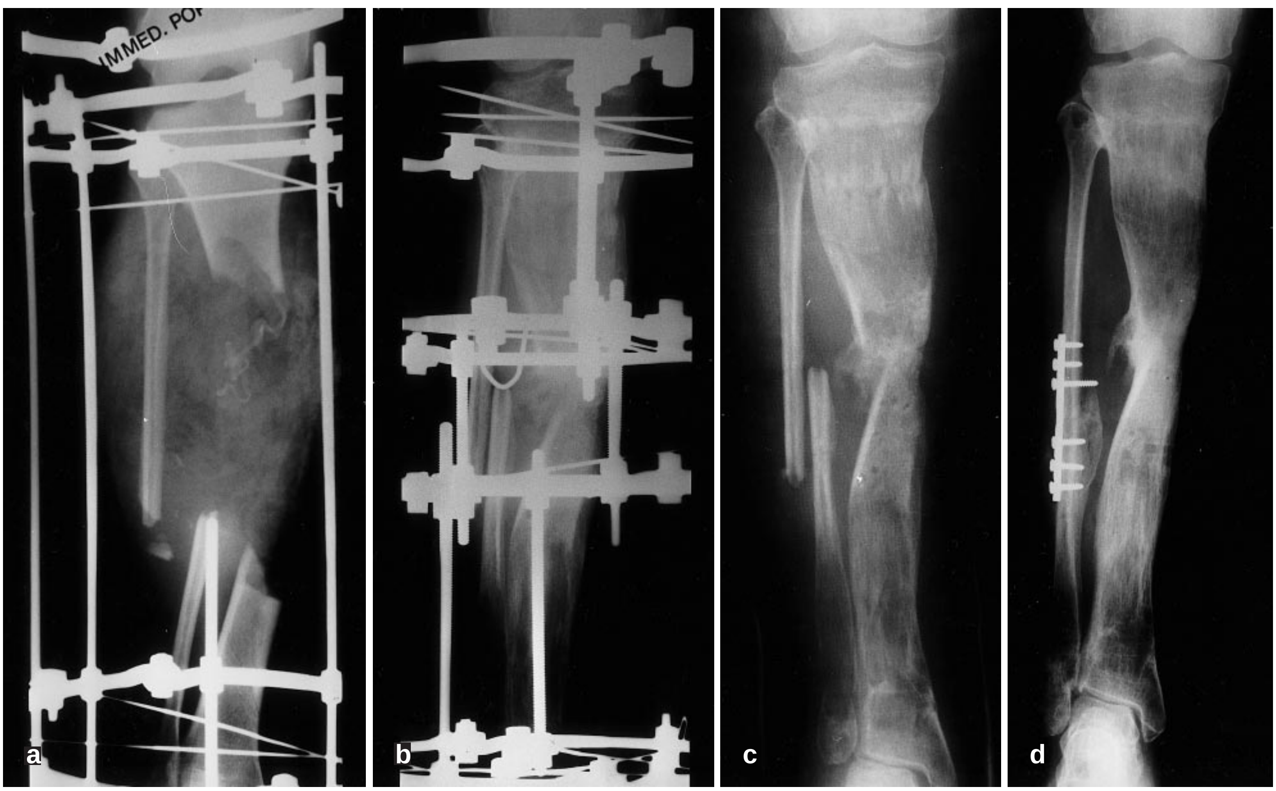

Fig. 2. a Tibial bone defect of 15 cm after debridement. **b** Proximal and distal tibial corticotomies were performed for internal bone transport. **c** Valgus deformity of the ankle which resulted from proximal migration of the distal fibula. **d** The distal fibula was gradually transported with the Ilizarov apparatus and fixed with a plate and screws. A normal ankle mortise was restored after distal transportation of the fibula

Table 1. Classification of the results according to the modified ASAMI classification

Bone		Functional result
Excellent	Bone union, no infection deformity <7° LLD <2.5 cm	Ability to perform previous activities of daily living (ADL), no pain or mild pain No limp, no soft tissue sympathetic dystrophy Knee or ankle joint contracture <5° Loss of ankle or knee motion <15°
Good	Bone union Failure to meet one of the other criteria	Almost all ADL with minimal difficulty No pain or mild pain Failure to meet one of the other criteria
Fair	Bone union Failure to meet two of the other criteria	Most ADL with minimal difficulty No pain or mild pain Failure to meet two of the other criteria
Poor	Nonunion or refracture Failure to meet three of the other criteria	Significantly limited ADL Significant pain requiring narcotics Failure to meet three of the other criteria

grade IIIB in 8, and grade IIIC in 3. All patients had normal sensation in the sole. Arteriography was performed in the open grade IIIC fractures before application of the Ilizarov apparatus. Eleven of 13 segments with infected non-union had active purulent drainage. At the time of the Ilizarov treatment, after radical debridement, the average length of the bone defect in the infected non-union was 8.2 cm (range 3–17 cm).

Of 27 segments, 16 had undergone previous surgical intervention. The average number of prior operations was 6 (range 1–9). In 27 internal bone transports, one-level tibial corticotomy was performed in 20, two-level tibial corticotomy in 3, two-level tibial corticotomy with fibular corticotomy in 1 (Fig. 1), fibular transport in 2, and one-level tibial corticotomy with fibular transport in 1. The average length of transport was 7.1 cm (range 2–20 cm).

Three fibulae were transported when the tibiae were not available for transport because of inadequate residual tibial length. The transported lengths of the 3 fibulae were 12 cm, 15 cm, and 21 cm. Of the ipsilateral fibulae, two were transported acutely and one was transported gradually, using the Ilizarov apparatus (Fig. 2).

Twenty-five of 27 segments were treated for early union or infection control with cancellous bone grafting at the docking site after bone transport. Of 25 bone graftings, 11 were performed with a Papineau-type open cancellous procedure for the treatment of infection and soft tissue loss. Methylmethacrylate, mixed with antibiotics, was inserted at the site of the defect in 7 segments in order to prevent recurrence of infection and to avoid soft tissue obstruction during internal bone transport. The cement beads, strung along nylon suture threads, were removed gradually through a small skin incision.

Sixteen large soft tissue loss required secondary operation. Six segments underwent soft tissue coverage with a rotational muscular flap in 3 and a free flap of the latissimus dorsi muscle in the other 3 to obtain coverage of exposed bone. The remaining 10 segments with soft tissue loss were treated by soft tissue transport using a transverse ring system. Skin grafts were performed on 12 segments. Ten segments had acute docking or shortening of the site of the defect in order to reduce or cover the soft tissue gap. Acute shortening provided soft tissue reduncancy which covered the exposed bony area. In these segments, a one-stage operation involving corticotomy, acute docking, and cancellous bone grafting was performed.

The radiographic consolidation index (RCI: months until radiographic consolidation per centimetre of distraction), the percentage of transport (percentage of overall tibial length regenerated), external fixation time (EFT), and the time to union, were calculated.

The results were divided into bone and functional categories, according to the classification of the Association for the Study and Application of the Method of Ilizarov (ASAMI) (Table 1). The bone results were based on four criteria: union, infection, deformity and leg length discrepancy. Functional results were based on five criteria: presence of a limp, stiffness of the knee or the ankle, pain, soft-tissue sympathetic dysfunction, and the ability to perform previous activities of daily living (ADL).

Table 2. Complications and treatment

Complications (No.)	Treatment (No.)
Valgus deformity of ankle (2)	Distal fibular transport (1), No treatment (1)
Malunion (5)	No treatment (5)
Residual tibial shortening (10)	Tibial lengthening (2), No treatment (8)
Stress fracture during corticotomy (3)	No treatment (3)
Refracture (3)	Conservative treatment (2) Closed reduction and intramedullary nailing (1)
Recurrent osteomyelitis (1)	Radical debridement and bone grafting (1)
Delayed union (1)	No treatment (1)
Equinus or equinovarus (4)	Percutaneous tendocalcaneal lengthening & extended foot frame (1), No treatment (3)
Ankle stiffness with plantigrade foot (9)	No treatment (9)
Knee flexion contracture (1)	Extended knee frame (1)
Soft tissue invagination (3)	Elevation of soft tissue (3)

Results

The average time of follow-up was 2.5 years (range 1.5 to 4 years). Bone union was obtained in every patient. The average time to union was 7.1 months (range 4–10 months). The average EFT was 8.0 months (range 4–11.4 months). The average radiographic consolidation index of the distraction gap was 1.3 months/cm (range 1–4 months/cm). The EFT was related to the period of radiographic consolidation of the distraction gap when the gap was more than 7–8 cm because cancellous bone grafting reduced the EFT at the docking site. The average percentage of tibial distraction, relative to the overall tibial length, was 27% (range 10–50%). The bone results were rated as excellent in 14 segments, good in 8, fair in 2, and poor in 3. The functional results were rated as excellent in 11 segments, good in 11, fair in 2, and poor in 3. Pin tract infection was the most common complication. Skin and soft tissue infections were treated with oral antibiotics and antibiotic injections around the pin tract. Infection of either the soft tissue or pin tracts did not result in osteomyelitis. Other complications, which occurred in 15 patients, are listed in Table 2.

Discussion

The Ilizarov method overcomes complications of bone grafting by providing distraction osteogenesis which serves as a vascularised cancellous bone graft to fill bone defects. With this method, early full-weight bearing is possible, and infection can be treated with lower recurrence because of increased blood flow during distraction [15].

Controversy exists concerning the use of bone grafting at the docking site at the conclusion of bone transport with the Ilizarov method. Paley et al. [19] and Cattaneo et al. [5] reported that all their patients (25 and 28, respectively) who had tibial non-union and bone loss obtained bone union at the docking sites with compression only, without bone grafts. There was, however, delayed consolidation at the docking sites which necessitated a further period of 2 months to obtain union after consolidation of the distraction site. Several authors [9, 16, 26] who initially used only compression have reported that 5–67% of their patients required bone grafts at the docking site in order to obtain bone union after failure to unite. To obtain union at the docking site using only compression, it is recommended that radical debridement to the point of exposing the fresh cortical end and restoration of the medullary canal should be performed.

In our series, 25 of 27 segments had early bone grafting at the docking site in order to shorten the length of treatment and to widen the contact area when the end of the proximal or distal fragments were spiral or oblique. Bone union was obtained in all segments at this site. The average time in external fixation was 8 months and the average time to union was 7 months. On a basis of these results, it is apparent that bone grafting at the docking site can decrease the time for external fixation and prevent delayed union or non-union.

The advantages of performing a one-stage operation, include the avoidance of secondary operations such as bone grafting and a reduced treatment time. In our series, acute docking and acute shortening were each performed in 5 segments. Acute docking was possible for bone defects of less than 6 cm. A bone defect of more than 7 cm precludes acute docking because of the possibility of kinkage of vessels which would result in vascular insufficieny [3]. For this reason, acute shortening is preferable to acute docking.

Redundant soft tissue which results from acute docking or shortening is used to cover the exposed bony area. This technique improves the circulation when there is arterial insufficiency due to arterial distraction at the time of initial injury. If an infected non-union is associated with equinus deformity or knee flexion contracture, these may be managed by using the gastrocnemius muscle redundance, which is a consequence of acute shortening. In our series, the equinus deformities associated with infected non-union were corrected by acute shortening, with or without percutaneous lengthening of the achilles tendon, while the ankle was fixed with an extended foot frame, which is needed because the relaxed gastrocnemius muscle causes weakness of push-off.

Malunion or malalignment at the docking and distraction site occurs because of malalignment of the Ilizarov assembly and muscle contracture. In our study, 5 segments with proximal to distal transport had anterior angulation at the distraction site and posterior angulation at the docking site. These axial deviations resulted from tilting of the middle bone segment in the sagittal plane, due to imbalance of tension between the muscles of the posterior and anterior compartments. In the coronal plane, this tilting can produce medial angulation at the docking site and lateral angulation at the distraction site as a result of muscle contracture. Malalignment can be prevented with half-pin fixation of the middle segment. Insertion of two half-pins at a 90° angle provides more stability than Ilizarov wire fixation, which can resist muscle contracture. Bone transport over intramedullary nailing is another method of preventing malalignment [4, 22].

Conventional management is usually successful in the treatment of bone defects measuring less than 6 cm [18]. The functional results achieved in our series of patients with larger bone defects are of considerable interest. The average bone defect in this group was 11.3 cm, and we obtainied 3 excellent, 8 good, and 5 fair or poor results. Ten of these patients developed a reduction in the range of movement in the ankles, 3 had an equinus deformity and two had a painful limp. Large bone defects of this magnitude are usually associated with severe soft tissue trauma. Of 16 patients with bone defects larger than 6 cm, 5 required free or rotational muscular flaps and 7 needed skin grafts. Transport of the bone in these circumstances inevitably causes a change in the anatomical relationship of the muscles, often rendering them mechanically disadvantaged. This may lead to a reduction in the range of motion of the distal joints, which may be further compromised by the associated vascular and lymphatic stasis arising from kinking and dependency.

Complications in bone transport resulted more frequently from muscle contractures during transport than from the process of bone healing itself. Our results suggest that the Ilizarov method is a useful procedure for bone healing. Nevertheless, careful examination during follow-up is necessary for obtaining results which are better than conventional treatment. Bone grafting at the docking site is recommended in order to obtain early union, to shorten external fixation time, and to avoid refracture.

Acknowledgements. We appreciate the assistance of Gabriela Tymowski (MA, Kinesiology) in the preparation of this paper.

References

1. Aronson J, Johnson E, Harp JH (1989) Local bone transportation for treatment of intercalary defects by the Ilizarov technique. Clin Orthop 243: 71–79
2. Banic A, Hertel R (1993) Double vascularised fibulas for reconstruction of large tibial defects. J Reconstr Microsurg 9A: 421–428
3. Broughton NS, Olney BW, Menelaus MB (1989) Tibial shortening for leg length discrepancy. J Bone Joint Surg [Br] 71: 242–245
4. Brunner UH, Cordey J, Schweiberer L, Perren SM (1994) Force required for bone segment transport in the treatment of large bone defects using medullary nail fixation. Clin Orthop 301: 147–155
5. Cattaneo R, Catagni M, Johnson EE (1992) The treatment of infected non-union and segmental defects of the tibia by the methods of Ilizarov. Clin Orthop 280: 143–152
6. Chew WYC, Low CK, Tan SK (1995) Long-term result of free vascularised fibular graft. Clin Orthop 311: 258–261
7. Christian EP, Bosse MJ, Robb G (1989) Reconstruction of large diaphyseal defects without free fibular transfer, in Grade-IIIB tibial fractures. J Bone Joint Surg [Am] 71: 994–1004
8. De Boer HH, Wood MB (1989) Bone change in the vascularised fibular graft. J Bone Joint Surg 71: 374–378
9. Dendrinos GK, Kontos S, Lyritsis E (1995) Use of the Ilizarov technique for treatment of non-union of the tibia associated with infection. J Bone Joint Surg [Am] 77: 835–846
10. Freeland AE, Mutz SB (1976) Posterior bone-grafting for infected ununited fracture of the tibia. J Bone Joint Surg [Am] 58: 653–657
11. Gordon L, Chiu EJ (1988) Treatment of infected nonunions and segmental defects of the tibia with staged microvascular muscle transplantation and bone-grafting. J Bone Joint Surg [Am] 70: 377–386
12. Green SA, Dlabal TA (1983) The open bone graft for septic non-union. Clin Orthop 180: 117–124
13. Green SA, Jackson JM, Wall DM, Marinow H, Ishkanian J (1992) Management of segmental defects by the Ilizarov intercalary bone transport method. Clin Orthop 280: 136–142
14. Green S (1994) Skeletal defects: A comparison of bone grafting and bone transport for segmental skeletal defects. Clin Orthop 301: 111–117
15. Ilizarov GA (1992) Transosseous osteosynthesis. Springer, Berlin, pp 168–183
16. Lenoble E, Lewertowski JM, Goutallier D (1995) Reconstruction of compound tibial and soft tissue loss using a traction histogenesis technique. J Trauma 39: 356–360
17. Low CK, Pho RH, Kour AK, Satku K, Kumar VP (1996) Infection of vascularised fibular grafts. Clin Orthop 323: 163–172
18. May JW, Jupiter JB, Weiland AJ, Byrd HS (1989) Current concepts review. Clinical classification of post-traumatic tibial osteomyelitis. J Bone Joint Surg [Am] 71: 1422–1428
19. Paley D, Catagni MA, Argnani F, Villa A, Benedetti GB, Cattaneo R (1989) Ilizarov treatment of tibial non-union with bone loss. Clin Orthop 241: 146–165
20. Papineau LJ (1973) L’excision greffe avec fermeture cutanee retardee diliberee dans l’osteomyelite chronique. Nouv Presse Méd 2: 2753–2755
21. Papineau LJ, Alfageme A, Delcourt JP, Pilon BL (1979) Chronic osteomyelitis: open excision and grafting after saucerization. Int Orthop 3: 165–176
22. Raschke MJ, Mann JW, Oedekoven G, Claudi BF (1992) Segmental transport after unreamed intramedullary nailing. Clin Orthop 282: 233–240
23. Roy-Camille R, Reigner B, Saillant G, Berteaux D (1976) Resultats de l’operation de Papineau. Rev Chir Orthop 62: 347–362
24. Roy-Camille R, Reigner B, Saillant G, Berteaux D (1976) Technique et histoire naturelle de l’intervention de Papineau. Rev Chir Orthop 62: 337–345
25. Schapiro MS, Endrizzi DP, Cannon RM, Dick HM (1993) Treatment of tibial defects and non-unions using ipsilateral vascularised fibular transposition. Clin Orthop 296: 207–212
26. Suger G, Fleischmann W, Hartwig E, Kinzl L (1995) Open segmental bone transport. A therapeutic alternative in post-traumatic and osteitis soft tissue and bone defects. Unfallchirurg 98: 381–385
27. Tang CH (1992) Reconstruction of the bones and joints of the upper extremity by vascularised free fibular graft. J Reconstr Microsurg 8A: 285–292
28. Weiland AJ, Moore R, Daniel RK (1983) Vascularised bone autografts. Clin Orthop 174: 87–95