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Treatment of Non-Union After Tibial Shaft Fracture with a Full Cortical Thickness Inlay Bone Graft

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ABSTRACT

Twenty-seven non-infected delayed union or non-union fractures of the shaft of the tibia in 26 patients were operated on with a full cortical thickness inlay graft taken from the injured leg. The initial trauma was moderate in 9 fractures and severe in 18. Fifteen fractures were closed injuries and 12 open. The fracture pattern was longitudinal in 5 cases, transverse in 11 and communited in 11. Surgery was performed 12 to 72 weeks (mean: 30 weeks) after the fractures had been sustained.

All fractures healed after the bone grafting procedure. The time until union was established after surgery ranged from 6 to 37 weeks (mean: 17 weeks). The healing time was neither influenced by the initial type of fracture pattern ($p > 0.05$) nor by the fracture age at surgery ($r = -0.21$). Of 13 patients re-examined 8 to 16 years after surgery, the clinical results were classified as excellent in 8, as fair in 2, and as poor in 3 patients.

INTRODUCTION

Delayed union and non-union are well known complications in fractures of the shaft of the tibia. Albert (2) reviewed 395 tibial fractures and found an incidence of delayed union or non-union of 29 per cent. Brumsback (4) reported that 22 per cent of 120 tibial fractures had to be operated on to obtain union. Urist et al. (14) estimated that approximately one-third of all tibial fractures will present problems with union. Factors such as initial fracture displacement, comminution, associated soft-tissue injuries and wound infections are known to influence fracture healing (7,12). In displaced, compound, comminuted tibial fractures, Carpenter et al. (5) reported an incidence of non-union of 75 per cent.

Over the years, many surgical procedures have been described for the management of non-union of diaphyseal fractures. They include different bone grafting procedures using onlay, barrelstave and cancellous bone graft, intramedullary nailing and compression plate osteosynthesis. In recent years electrical stimulation has also been applied. In 1930, Albee (1) described a sliding inlay graft technique for treatment of non-union of diaphyseal fracture taking a full cortical thickness graft from the fractured bone. The advantage of this procedure is that the graft provides both internal fixation and osteogenetic stimulus (9).

We have employed a modification of Albee's procedure in the treatment of delayed union and non-union of the shaft of the tibia and the purpose of this study was to review our experience with this surgical procedure.

PATIENTS AND METHODS

During the 8 year period from 1969 through 1977, 27 fractures of the shaft of the tibia in 26 patients were operated on for delayed union or non-union with a modification of Albee's sliding full cortical thickness inlay bone graft technique at the Departments of Orthopedics, Sahlgren Hospital, Göteborg, and Borås Hospital, Sweden. The medical records and available radiographs of these 26 patients were reviewed.

From the medical records and radiographs, information was collected about the patient's age and sex, the type of initial trauma, the fracture pattern, the soft-tissue injury, the primary treatment, the surgical treatment and the healing time.

The initial trauma causing the fracture was classified as severe or moderate (7). Severe trauma was defined as fractures sustained in traffic accidents or from falls from a height. For the remaining fractures, the trauma was classified as moderate.

Type of fracture pattern and soft-tissue injury were classified according to a modification of the classification used by Edwards (7). The fracture patterns were thus classified as transverse, oblique or comminuted when there was one or more intermediary fragment. Fractures with only minor puncture wounds were included in the group of open injuries.

Healing time was defined as the time when the fracture was determined, clinically and radiologically, to be united sufficiently well not to require further immobilization. In none of the patients did deformation or refracture occur after this time.

Statistics: Student's t-test for small samples was used and a p-value less than 0.05 was considered significant.

Surgical technique: The anesthetized patient is placed in the supine position on the operating table and a tourniquet is applied around the thigh. A slightly medially curved incision, about

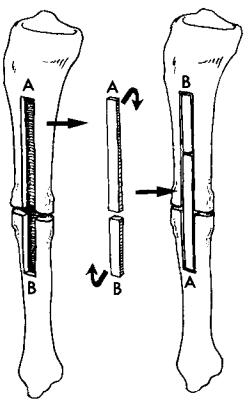

Figure 1. Modification of Albee's bone grafting procedure. From the anteromedial slide of the tibia a full cortical thickness bone graft of unequal length on either side of the fracture is taken out, turned 180 degrees and put back into the trough.

15 cm long, is made just medial to the anterior aspect of the tibia at the fracture site. The subcutaneous tissue and the periosteum are then incised along the skin incision and the periosteum is separated from the anteromedial side of the tibia "en-bloc" with the subcutaneous tissue and the skin. Reflecting the periosteum together with the soft-tissue, the tibia and the fractures are then exposed and, using an oscillating saw, a full cortical thickness graft, about 15 cm long and 1.5 cm wide, is taken out from the anteromedial side of the tibia (Figure 1). The graft, which must be of unequal length on either side of the fracture, is then turned 180 degrees and put back into the trough. The asymmetrical length of the graft will guarantee that the fracture space is covered by intact graft bone. When the graft fits firmly into the trough, internal fixation is not necessary. If this is not the case, however, internal fixation of the graft using screws may be necessary. At this stage, especially if there is still a considerable fracture gap, one may also have to consider cancellous bone grafting, taking bone grafts from the proximal end of the tibia, or preferably, from the iliac crest. As suggested by Phemister (13), however, it is recommended that the fibrous pseudoarthrosis be left intact. The periosteum is then sutured back and a Hemovac is routinely placed under the subcutaneous tissue and the operation wound is closed with loosely interrupted skin sutures. After wound dressing and after having removed the tourniquet, a long, non-weight-bearing, cast is applied. The long leg cast is kept until it is obvious, both clinically and radiologically, that fracture union has started. At that time, a patellar tendon-bearing full weight-bearing cast is applied which is kept on until union is solid.

RESULTS

Initial descriptive data. Of the closed injuries, 4 fractures were longitudinal, 9 transverse and 2 comminuted, and of the open injuries, 1 fracture was longitudinal, 2 transverse and 9 comminuted (Table 1). Sixteen fractures were initially treated with closed reduction and application of a long leg cast and 11 with open reduction, internal fixation and a long leg cast. All 12 open injuries were initially treated with debridement and 11 wounds were closed primarily and 1 was treated with delayed primary closure.

Table 1. Initial descriptive data on 27 fractures of the shaft of the tibia in 26 patients (20 male and 6 female) operated on for delayed union or non-union

Age (years)		Fracture pattern	
Range	17-74	Longitudinal	5
Mean	38	Transverse	11
		Comminuted	11
Initial trauma		Primary treatment	
Moderate	9	Closed reduction	16
Severe	18	Open reduction and internal fixation	11
Soft-tissue injuries		Initial treatment of soft-tissue injuries	
Closed injuries	15	Debridement and primary closure	11
Open injuries	12	Delayed primary closure	1

Bone grafting procedure: The fracture age when the bone grafting procedure was performed varied from 12 to 72 weeks (mean: 30 weeks) and was 20 weeks or more in 74 per cent of the fractures and 32 weeks or more in 33 per cent of the fractures (Table 2). The sedimentation rate at operation was available for 21 patients (81 per cent) and was 15 or less in 19 patients and 20 or more in 2 patients. At the time of surgery, 6 patients (23 per cent) received prophylactic antibiotic treatment and in all but 3 fractures additional cancellous bone grafting performed.

Table 2. Data on bone grafting procedure

Fracture age at surgery (weeks)		Internal fixation of the bone graft	
Range	12–72	None	13
Mean	30	Screws	12
		Cerclage	2
Sedimentation rate at surgery		Additional cancellous bone grafting	
Range	2-42	Yes	24
Mean	11	No	3

Healing time: Data on the healing time after surgery are summarized in Figure 2 and Table 3. All fractures healed after the bone grafting procedure. The time until union was established varied from 6 to 37 weeks (mean: 17 weeks) after surgery (Table 3). The initial fracture pattern did not influence the healing time after surgery significantly ($p>0.05$) although there was a tendency toward shorter healing time in longitudinal fractures. Further, there was no correlation between healing time after surgery and fracture age at surgery (correlation coefficient = –0.21).

Table 3. Healing time after surgery in relation to initial soft-tissue injury and type of fracture

Soft-tissue injury and Types of fracture	Number	Healing time (weeks) Range	Mean
All fractures	27	6.4–37.0	17.7
Closed injuries			
All fractures	15	7.6–28.7	17.8
Longitudinal	4	7.6–20.0	13.0
Transverse	9	12.1–28.7	19.7
Comminuted	2	15.3–23.6	19.5
Open injuries			
All fractures	12	6.4–37.0	17.5
Longitudinal	1	12.9	12.9
Transverse	2	12.1–19.3	15.7
Comminuted	9	6.4–37.0	18.4

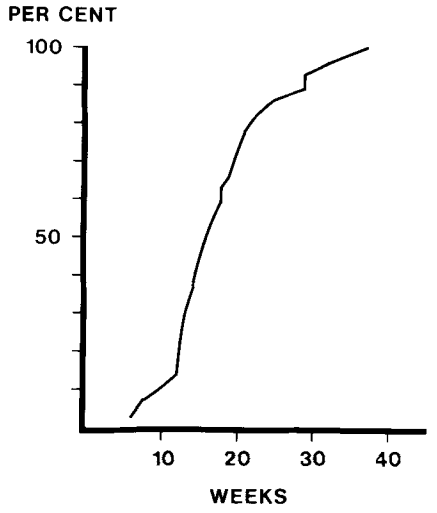

Figure 2. Percentage of united fractures in relation to weeks after surgery.

Clinical Results: In all, it was possible to re-examine 16 patients (62 per cent) 8 to 16 years (mean: 13 years) after they had sustained the fracture. Of the patients who were not re-examined, 7 were dead and 3 could not be traced. At the time of re-examination, 2 patients had been operated on with a total hip joint replacement and 1 for a hip fracture. In 12 patients, total ankle joint motion (summary of plantar flexion and extension) was restricted less than 20 degrees and in 4, 20 degrees or more. Of 13 patients who had not had hip surgery, all except one could walk unlimited distances and 10 were walking without limping while 3 had a slight limp. The clinical results in patients who had not had hip surgery were also classified by summary of the clinical findings and the patient's own assessment of their walking ability. In 8 patients who could walk unlimited distances without limping, and in whom total ankle joint motion was restricted less than 20 degrees, the results were classified as excellent; in 2 patients who could walk unlimited distances without limping but in whom total ankle joint motion was restricted 20 degrees or more as fair, and in 3 patients who could not walk unlimited distances and/or limped, they were classified as poor. Of the patients in whom the clinical results were classified as excellent, 4 had sustained the fracture by moderate trauma and 4 by severe trauma, whereas all 5 patients in whom the results were classified as fair or poor had sustained the fracture by severe trauma.

DISCUSSION

When evaluating fractures of the shaft of the tibia in which healing is not progressing at normal speed, it is essential to asses whether one is dealing with a delayed union or a non-union. Delayed union, by definition, means that a fracture has not united in the time period when that type of fracture is usually united. Non-union, on the other hand, means that the healing process has ceased (3). In clinical practice, it is often difficult, however, to apply these definitions correctly. As a guideline for the clinical management of fractures of the shaft

of the tibia, it has been suggested that delayed union be defined as absence of fracture healing, assessed both clinically and radiologically, at the fracture age of 20 weeks, and non-union as when a fracture is not united after 32 weeks (10). According to these definitions, 74 per cent of the fractures reported on in this study would be classified as having delayed union or non-union.

In non-infected non-union of tibial fractures several surgical procedures are possible alternatives, including internal fixation using a compression plate, an intramedullary nail, and a full cortical thickness inlay graft. It is usually recommended that internal fixation procedures, especially in "atrophic pseudoarthrosis", can be combined with cancellous bone grafting (11). To our knowledge, there are not yet enough published reports on these different techniques to allow conclusions as to whether any of these methods of treatment is superior. The compression plate offers rigid immobilization, which is often desirable, especially in "hypertrophic pseudoarthrosis", but has the disadvantage of causing bone resorption with an increased risk of re-fracture later. The plate also constitutes a foreign body, thereby increasing the risk of infection. Further, after union is established, the plate has to be removed and thus a second operation is required. The intramedullary nail does not have these disadvantages to the same extent and seems to be a suitable method for hypertrophic pseudoarthrosis in transverse undisplaced fractures. If the fracture is comminuted it can, however, be difficult to obtain adequate fixation. The full cortical thickness inlay graft has the advantage of offering internal fixation and stimulation of osteogenesis without osteosynthesis. To obtain internal fixation the graft must fit firmly into the trough, and this can be more easily achieved by using a twin-saw adjusted to the right width, as suggested by Albee (1930), than when a single-bladed saw is used. It is also essential to aim for optimal fit of the layers of the graft to the layers of the host and that the graft contain both cortex and marrow in sufficient amounts. The cortex of the graft will mainly provide internal fixation of the fracture fragments and the marrow will stimulate osteogenesis. Further, resuturing of the periosteum over the graft will reduce the risk for dislocation of the graft.

In 52 per cent (14/27) of the fractures in this study it was considered necessary to use internal fixation of the graft, probably due to the fact that a single-bladed saw had been used when taking out the graft and an accurate fit of the graft into the trough had probably not been obtained. In all except 3 fractures additional cancellous bone grafting was performed to obtain sufficient amount of medullary bone. By combining these two procedures, which is probably not routinely necessary, all the fractures healed. As the healing time after surgery was not influenced by the fracture pattern this procedure also seems to work well in non-infected transverse and comminuted fractures, usually caused by severe trauma, which are known commonly to present healing problems.

The clinical results were probably influenced more by the severity of the initial trauma than by the bone grafting procedure. Of 9 patients who had sustained the fracture by severe trauma the clinical results were classified as excellent in 4 and as fair or poor in 5, whereas in 4 patients who had sustained the fracture by moderate trauma the clinical results were classified as excellent in all cases.

CONCLUSIONS

In summary, we believe that the results of this study of treatment of 27 non-infected delayed union or non-union of fractures of the shaft of the tibia with a full cortical thickness inlay graft warrant the conclusion that this is a reliable surgical procedure which merits consideration in cases of healing problems in tibial fractures. Our present treatment policy for this condition is to use this method for non-infected atrophic pseudoarthrosis and in displaced fractures which cannot be treated with closed intramedullary nailing. In hypertrophic pseudoarthrosis of the middle third of the tibia in undisplaced transverse fractures, however, we now prefer rigid closed intramedullary nailing.

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