Complex nonunion of fractures of the femoral shaft treated by wave-plated osteosynthesis


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COMPLEX NONUNION OF FRACTURES OF THE FEMORAL SHAFT TREATED BY WAVE-PLATE OSTEOSYNTHESIS

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We have treated 42 consecutive complex ununited fractures of the femoral shaft by wave-plate osteosynthesis at five different medical centres. There were 13 with previous infection, 12 with segmental cortical defects, and 3 were pathological fractures. In 39 cases there had been previous internal fixation and 21 patients had had more than one earlier operation.

Union was achieved in 41 patients at an average of six months, although three had required a second bone graft. Two patients had recurrence of infection and in one this resulted in the persistence of nonunion. There were no failures of the implant. All 41 patients with union are now fully weight-bearing, but four have a leg-length discrepancy, one has axial malalignment, and nine have residual stiffness of the knee. These results are surprisingly good, despite the complexity of the initial problem, and appear to confirm the biological and mechanical advantages of the wave plate over the conventional plate for such cases.

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It is difficult to achieve union of an ununited fracture of the femoral shaft or osteotomy when the intrinsic or extrinsic blood supply has been damaged by infection or multiple operations, or if bone has been lost or is abnormal. The results of internal fixation with an intramedullary nail or a conventional plate combined with autogenous cortico-cancellous or vascularised bone grafts or allografts are unpredictable.

Blatter, Gasser and Weber first suggested the use of wave-plate osteosynthesis. The wave plate has a contour bent into its midportion so that it stands away from the bone at the abnormal area. It is claimed to have both biological and mechanical advantages. Its use preserves the local blood supply by reducing the need for operative dissection and the area of plate-bone contact. It also allows autogenous bone grafts on the lateral cortex to share the axial compressive loads with the plate more effectively.

We report a retrospective review of the use of the wave plate in the treatment of complex, ununited fractures of the femoral shaft in 42 consecutive patients.

PATIENTS AND METHODS

Between November 1985 and February 1992, 42 patients with ununited fractures of the femoral shaft were treated by a wave plate combined with bone grafting. This series represents consecutive operations at five different medical centres. The limited indications for this operation have been discussed above; all ununited fractures of the femoral shaft managed by conventional internal fixation and bone grafting have been excluded.

The average age of the patients was 35 years (13 to 81); 29 were male and 13 female. The failure of union followed an osteotomy in four patients, a leg-lengthening procedure in two and a fracture in 36. Three of the fractures were through abnormal bone: one through a metastasis of a renal-cell carcinoma, one through a fibrosarcoma and one at the site of old chronic osteomyelitis. The other 33 fractures were traumatic in origin; they were caused by a fall in four patients, a motor-vehicle accident in 28 and a motorcycle accident in one. Eight of the fractures were open.

The initial treatment had included intramedullary fixation in three of the four osteotomies and five of the fractures,
A 75-year-old man sustained a fracture of his left proximal femur at the site of a metastasis from a renal-cell carcinoma. The initial fixation was by a condylar blade plate. Methylmethacrylate cement was placed in the fracture site (a,b). Failure of union was treated by a second plating with an intramedullary Rush rod, more cement and autogenous cancellous bone grafting (c), but one year later the second plate fractured and the fracture remained ununited (d). Four years after wave-plate osteosynthesis anteroposterior and lateral radiographs show healing of the fracture (e,f), and this remained intact at eight years (g).
supplemented by a cerclage wire in one. The fourth osteotomy and the three fractures through abnormal bone had been fixed by a plate and screws. Methylmethacrylate had been used to fill the metastatic lesion and in the other two cases with abnormal bone autogenous cancellous bone from the iliac crest was used. Of the remaining fractures, 24 had been treated by a plate and screws, one by pins incorporated into a plaster cast, two in skeletal traction, and one in a hip spica.

The average duration of nonunion before the wave-plate osteosynthesis was 17 months (6 to 86). One or more secondary operations had been performed in 21 patients (mean 2; range 1 to 6) (Fig. 1 and Table I). There were segmental cortical defects in 12 patients with an average bony defect of 4 cm (1 to 8).

In 13 patients, there had been infection either after the initial operation or a secondary procedure. The organism responsible was *Staphylococcus aureus* in five with *Klebsiella pneumoniae* as a second organism in one, *Staphylococcus epidermidis* in five, *Klebsiella pneumoniae* alone and *Pseudomonas aeruginosa* in one patient each. In the patient with a history of chronic osteomyelitis, *Staphylococcus aureus* had been isolated from the original infection. Before the wave-plate procedure in this patient, infection had been treated by operations for debridement and culture of the organism to enable specific parenteral antibiotics to be used. No fracture was actively discharging at the time of the wave-plate operation. Details of the patients are given in Table I.

**Operative technique.** The ununited fracture was stabilised by a wave plate and screws and then grafted with autogenous corticocancellous bone from the iliac crest. In four

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* unless stated otherwise, patients were fully weight-bearing, had equal leg length (LL) and a full range of knee movement (ROM; degrees)
patients with large bony defects (mean 7.5 cm) a vascularised fibular graft was also used. In one patient an allograft bone was used to supplement the autogenous graft.

Preoperative planning included the use of an overlay technique using radiographs of the uninvolved side to determine the ideal bony alignment and the length, size and contour of the plate. At operation, the exposure was limited to the portion of the bone on which the plate would lie. An AO/ASIF femoral distractor (Synthes Ltd, Paoli, Pennsylvania) was applied and used to correct the length and alignment of the femur without direct exposure or manipulation of the abnormal area. This technique reduced the need for stripping and devitalising soft tissue.

The AO/ASIF compression plate (Synthes Ltd, Paoli, Pennsylvania) was contoured using a plate-bending device to provide three or four gently sloping bends to lift the midportion of the plate 0.5 to 1.0 cm away from the bone in the region of the nonunion. The bends were placed in order to avoid direct contact with bone within the distance of one screw hole both proximally and distally from the abnormal area. The length of the plate was chosen so that at least three screws could be placed both proximally and distally. More were used if the underlaying bone was seen to be osteoporotic. We used a 4.5 mm broad dynamic compression plate in 35 patients with an average length of 14 holes (10 to 21). Three patients had condylar blade plates, two with 12 holes and one with 20 holes. Two had dynamic condylar screw-plates 14 holes in length, one had a 16-hole condylar buttress plate and one a 13-hole limited contact 4.5 mm dynamic compression plate (Synthes Ltd, Paoli, Pennsylvania). Corticocancellous bone graft from the iliac crest was placed between the plate and the bone across the abnormal area (Fig. 2).

Postoperative management included exercises for the hip and knee, starting on the second or third day. Union was judged clinically by the absence of pain on weight-bearing and on radiographs by evidence of incorporation of bone graft at the site of nonunion and cortical changes in the cancellous graft. Weight-bearing on the operated leg was limited until radiographs showed evidence of union. A progressive increase in weight-bearing was then allowed. All patients were reviewed at regular intervals with serial radiographs and clinical examination. At final follow-up, the capacity to bear weight, any leg-length discrepancy, alignment and the range of movement in the joints of the leg were noted.

RESULTS

The mean follow-up was 33 months (12 to 66) (Table I). The nonunion had healed in 41 patients at an average of 6 months (3 to 18).

Two patients with previous infection had recurrence. One of the fractures failed to unite; the other healed, but developed a draining fistula. Another patient with persistent nonunion had a second bone-grafting procedure 12 months after the insertion of a wave plate and the fracture had united by 18 months. Two of the four patients in whom a large bony defect had been treated with a vascularised fibular graft required an additional grafting procedure before union.

All 41 patients in whom union had been achieved were able to bear full weight without pain at the latest follow-up (Table I). There was a leg-length discrepancy in four patients, with an average shortening of 2 cm (1 to 2.5). One patient healed with 16° varus angulation. All patients had full mobility at the hip and ankle, and 31 regained full movement at the knee. Seven had residual limitation of knee flexion and two lacked 10° of extension. One patient with severe limitation of knee flexion required quadriceps lengthening, which gave a range of 1° to 60° at the latest follow-up. One patient had residual knee instability.

One patient whose fracture had healed and who had resumed full weight-bearing had a fungaemia during the treatment of an autoimmune disorder with immunosuppressive drugs two years after the wave-plate procedure. This led to catastrophic infection and amputation was necessary two years later.

DISCUSSION

A wave-plate osteosynthesis combines a number of features of ‘biological plating’.11-17 It emphasises preservation of the residual blood supply to the bone and surrounding soft tissues. Bone healing is enhanced beneath the plate both by the graft and by a better mechanical environment.11

The use of wide exposures for injuries or reconstructive surgery of the femoral shaft has decreased because of problems inherent in the manipulation of the skeletal fragments at operation18 and the development of versatile intramedullary nails which can be inserted with minimal exposure.19-22 Our series was treated using indirect bone reduction. Axial realignment and bone lengthening were achieved by the use of a femoral distractor applied to the femoral shaft proximal and distal to the ununited region.8,13,15 The Schantz screws used to attach the distractor to the bone were inserted in the plane of the deformity, either through the wound or percutaneously. This enabled realignment without the use of bone clamps or retractors which would threaten the circulation at the site of application.

This emphasis on the preservation of the blood supply is of fundamental importance for the reincorporation of iliac-crest bone graft, placed between the plate and the bony defect.

On the femoral shaft, a plate provides the best stabilisation when it is applied as a tension band on the lateral aspect. The bone itself then absorbs the axial compressive forces.24-26 Plates are weakest in bending and torsion and will fatigue and ultimately fail if they are cyclically loaded in these modes.24,25 In the presence of medial or segmental...
A 16-year-old woman sustained a pathological fracture of her femur through a fibrosarcoma which was successfully treated by resection, radiation and chemotherapy. The initial plate fixation with autogenous cancellous bone graft failed to heal and the plate fractured (a,b). A second plate and graft also failed (c,d). Two years after wave-plate osteosynthesis, the fracture had united (e,f) and remained satisfactory at seven years (g,h).
bony defects, as in our series, a conventional plate is subjected to a local concentration of bending forces which may induce failure; 28 the contouring of a plate into a wave form enhances its mechanical role. The bends in the plate could have an adverse effect by increasing the moment arm, 14,25,26 but an intact or reconstituted lateral cortex will support the compressive forces on the femur and allow the plate to function as a lateral tension band. 9,11

A complete segmental bony defect will allow the plate to be subject to cyclical bending loads until the bone graft has consolidated, but the long contour of the bent section may be less likely to fail than a conventional plate because cyclical loading is distributed over a wide area rather than at a local fulcrum. Biomechanical tests have shown that the wave plate tended to fail at a remote screw hole rather than at the axis of the bending moment. 9

The use of a more flexible section of plate deviates from the theoretical goal of inherent stability of a plate-bone construct. 29 This theory was based on the principles of direct bony apposition, prevention of movement at the fracture or nonunion and axial compression, often enhanced by interfragmentary screw fixation. 24 The aim was the so-called primary bone healing. The flexibility of the wave-plate configuration is intended to transfer load to healing bone and thereby enhance callus formation. 20,22 Decreasing stiffness of plates has been shown to promote more vigorous callus formation in a rabbit model. 30

Our results have shown that wave-plate osteosynthesis for complicated nonunion of the femoral shaft gives a high rate of eventual union with no failures of the implant. Complications were few and the functional results were generally good. The success of the wave plate derives from both biological and mechanical advantages over conventional plate fixation.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES