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The use of interlocked 'customised' blade plates in the treatment of metaphyseal fractures in patients with poor bone stock

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Abstract

Balanced and stable fixation in metaphyseal fractures and nonunion can be difficult because of osteoporosis, disuse osteopenia, comminution, joint proximity or malignant infiltration. Five patients with nonunion and four with comminuted or pathological acute fractures of metaphyseal areas of the tibia or humerus were treated with a 'customised' interlocked blade plate. The plates are standard AO dynamic compression plates of a suitable length that are bent to an acute angle in an industrial vice and 'interlocked'. The nine patients with a mean age of 62.2 years (range 30–91) were followed up for a mean of 7.2 months.

At follow-up all fractures had healed with a single complication of subacromial impingement in a patient with a proximal humeral fracture. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

Balanced stable fixation in metaphyseal fractures and nonunion can be a difficult problem. Reasons for this may include: osteoporosis or disuse osteopenia, comminution or limited metaphyseal bone volume, joint proximity and malignant infiltration preventing adequate screw purchase. Standard fixation techniques and implants may be inadequate in such cases to secure fixation to allow early functional recovery [1]. The failure of previous fixation devices may further compromise available bone stock. We report on nine patients with such 'problem fractures' who have been treated with a 'customised' interlocked angled plate (see Fig. 1).

2. Patients and methods

The individual patients are described in Table 1.

There were five nonunion patients as follows:

1. infected nonunion 8 months following hybrid external fixation of a closed fragmented tibial plateau fracture.
2. nonunion of a nonoperatively treated proximal humeral fracture six months after injury.
3. nonunion of an open proximal humeral fracture 14 months after injury that had been treated twice with dynamic compression plating.
4. nonunion of an open transverse fracture of the distal tibia that had been treated with an external fixator (see Fig. 2).
5. nonunion of a fracture of the proximal tibia that had been treated nonoperatively.

There were four patients with 'fresh fractures':

1. two had proximal tibia fractures with poor quality bone stock secondary to osteoporosis (see Fig. 3).
2. two had proximal tibia fractures with poor quality bone stock secondary to osteoporosis (see Fig. 3).
3. a comminuted proximal humeral fracture.
4. a pathological fracture from a malignant bony metastasis in the proximal humerus (see Fig. 4).

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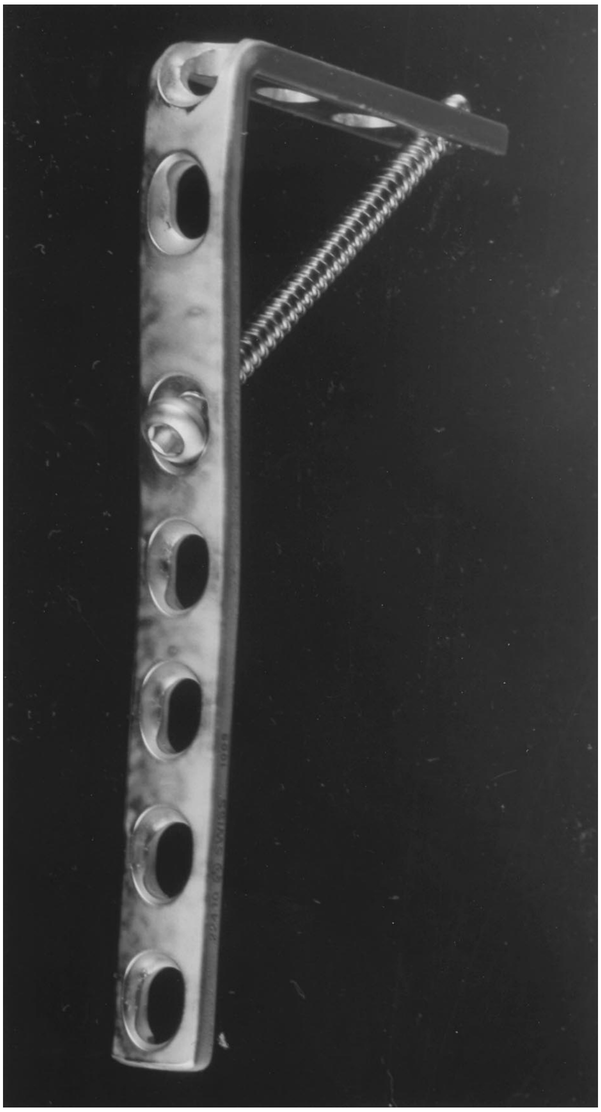

Fig. 1. The 'customised' blade plate demonstrating the interlocking screw in place prior to sterilisation.

There were no intraoperative complications and no postoperative wound infections.

Postoperatively all the patients with tibial fractures were mobilised in a cast brace, touch weight bearing for three months before progressing to full weightbearing once callus was seen on X-ray. The patients with shoulder fractures were mobilised with active assisted exercises for six weeks increasing to active resisted exercises once callus was seen.

3. Operative technique

The principles of technique were the same in all patients. Preoperative planning with radiographs and templates is essential to decide on the appropriate plate length and shape. There should be at least 10 holes to allow a minimum fixation of six cortices in the diaphyseal fragment and two holes to sit within the weak metaphyseal bone. A 3.5-mm dynamic compression plate (DCP) proved to be suitable for the humerus and 4.5 mm DCP for the proximal tibia. A 16 hole pelvic reconstruction plate was used in one patient as this allowed better contouring. The plate is prebent to the planned acute angle in an industrial vice. The angle of the bend of the plate will determine the number of interlocking screws that can be inserted, i.e., more than a right angle usually allows two screws to be successfully interlocked. The plate-to-plate interlocking screw is tested before sterilisation of the implant and the appropriate screw lengths determined.

After an appropriate exposure with minimal soft tissue dissection the entry site is chosen, usually in the middle of the metaphyseal fragment and checked with an image intensifier. Using a small chisel or drill a small cortical aperture is created to accept the shaped 'blade' of the plate. The plate is inserted with hand pressure or light hammer blows. The distal fragment is then reduced onto the vertical limb of the plate and held with a bone clamp. The selected compression and/or bone grafting techniques are performed. Two

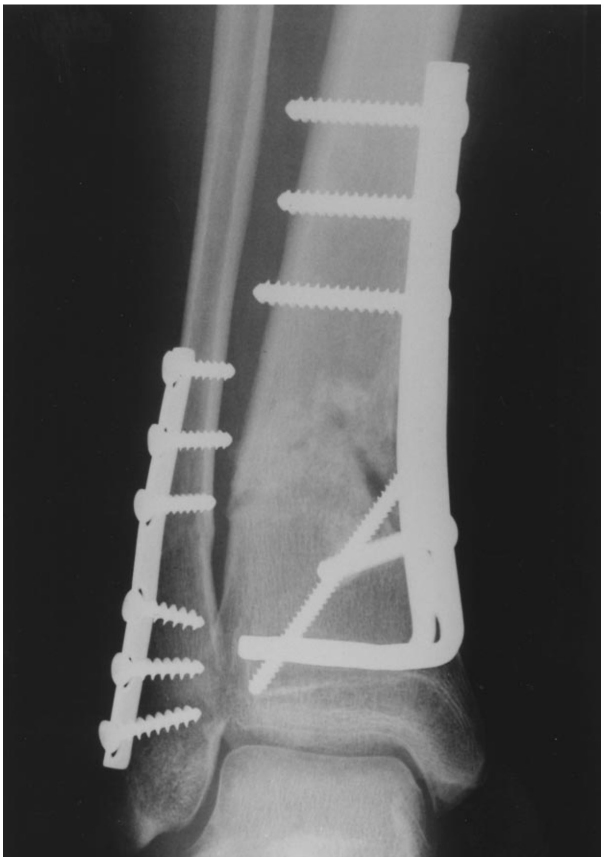

Fig. 2. Case 8: nonunion of distal tibia fracture treated with customised interlocked blade plate.

Table 1
Table of patients[a]

Case	Age (years)	Type of fracture or nonunion	Time to union after fixation (months)	Complications	ROM (compared to opposite side) (°)
Case 1	30	nonunion of fragmented proximal tibial fracture at 8 months treated with hybrid ex-fix	8	nil	0–100 (0–140)
Case 2	86	Short oblique fracture proximal tibia	4.5	nil	0–95 (0–110)
Case 3	91	nonunion of transverse fracture of surgical neck of humerus at 6 months	5	impingement of plate	Ab 80 (120), F 70 (110), ER 10 (20)
Case 4	47	Short oblique fracture proximal tibia below stiff knee (1987-distal femur fracture with quads tethering)	5	nil	5–50 (0–120) but preinjury ROM only 5–60
Case 5	53	Pathological fracture proximal humerus through myeloma metastasis	9	nil	Ab 90 (140), F 90 (120), ER 10 (40)
Case 6	68	Fragmented fracture proximal humerus	6	nil	Ab 80 (120), F 90 (130), ER 20 (30)
Case 7	60	nonunion open fracture shaft humerus at 8 months following DCP plating x 2	5	nil	pt not available for clinical review (returned to Nairobi)
Case 8	45	nonunion open transverse fracture distal tibia at 5 months treated with ex-fix	7	nil	DF 10 (20), PF 30 (40)
Case 9	80	nonunion transverse fracture proximal tibia at 4 months treated in POP	5	nil	0–110 (0–120)

[a] nb: ROM = range of motion, DCP = dynamic compression plate, POP = plaster of paris, Ab = abduction, F = flexion, ER = external rotation, DF = dorsiflexion, PF = plantarflexion.

holes just distal to the acute angle of the plate are left free to accommodate the interlocking screws. Holes are drilled through these holes and into the proximal fragment across into the holes of the horizontal limb of the plate. The plane of the plate is obvious to the surgeon.

Engagement of the drill and screw with the plate holes are monitored on the image intensifier with the beam perpendicular to the plate.

Appropriate sized cortical screws are then inserted and are felt to 'bite' on the plate holes in the proximal fragment. These are checked on the image intensifier and gently tightened. In the authors' experience an excellent purchase of the interlocking screws was obtained in all nine cases.

4. Results

The mean follow up was 7.2 months (range 4–10). All nine patients achieved clinical and radiological union during the period of follow-up (mean 6.1 months). All patients were satisfied with their outcome at follow-up, although a formal evaluation of outcome was not used. The only complication was that of subacromial impingement of the proximal blade plate in a 91-year-old patient (case 3) causing restricted abduction to 80°. However the patient was satisfied and did not wish to have any further surgical intervention.

5. Discussion

Bosworth first described the use of blade plates for the treatment of fractures of the surgical neck of the humerus in 1949 [2]. Blade plates have since been used for the treatment of fractures and nonunions of the proximal humerus [3–5] and also for rotational osteotomies for the treatment of recurrent dislocation of the shoulder [6,7]. Blade plates have also been used in the treatment of subtrochanteric and supracondylar fractures of the femur [1]. The advantages suggested in these papers include firm fixation in poor quality bone, good rotational control and the ability to apply compression at the fracture site. Soft tissue dissection is minimised. However, failure by pull-out of the blade of such unlocked devices is seen when satisfactory fixation to protect from varus or valgus strain cannot be achieved. Customised blade plates using modified 3.5- and 4.5-mm dynamic compression plates as fixed angled devices have been used with success to treat juxta-articular fractures and nonunions but without the interlocking modification described in this paper [8].

All the patients in this study had particularly poor bone density or limited periarticular bone presenting a

Fig. 3. Case 4: osteoporotic fracture of proximal tibia treated with customised interlocked blade plate.

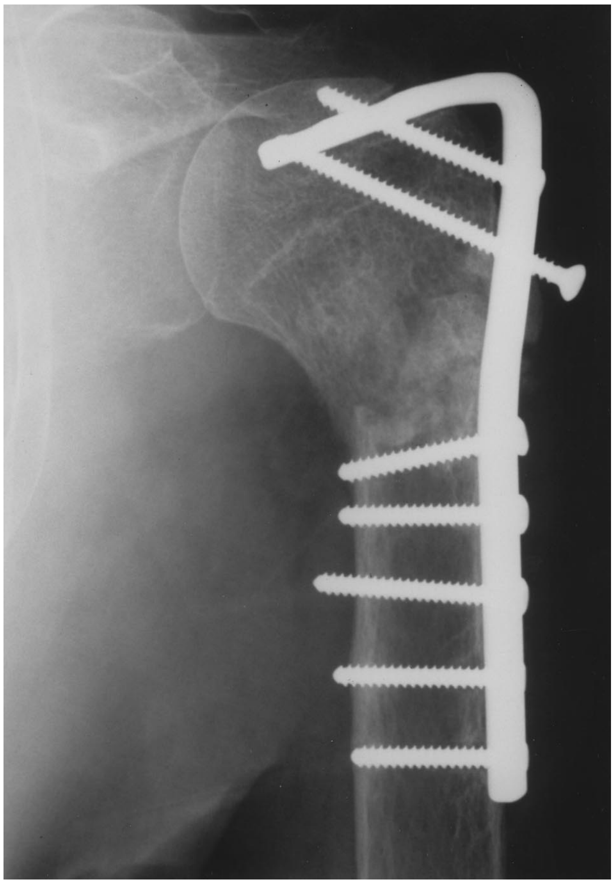

Fig. 4. Case 5: pathological fracture of proximal humerus treated with customised interlocked blade plate.

challenge for traditional implant fixation. The problem with fixation into such poor quality bone is that of limited screw purchase and the inability to spread the load forces equally through the bone.

The theoretical resistance to screw pullout is described in the equation:

$$F = (L/P) \times (C \times S) \times G,$$

where F is the pullout force, L the length of engagement of the screw, P the pitch, C the outer circumference of the screw, S the shear strength of the bone (poor in our patients) and G a geometric factor that accounts for the volume of bone into which the screw has purchase [9]. With the method of fixation described, one can see that as the interlocking screws pass into the proximal metaphyseal bone and then lock into the plate the shear strength against pull out is increased (i.e. S is increased). Because the screws are inserted in an oblique direction L is increased. Also the volume of bone 'behind' the screw is increased, thereby increasing the value of G i.e. the construct is more able to resist pull-off in a direction perpendicular to the bone. A recent biomechanical study analysed the effect of an oblique screw through a lateral condylar buttress plate in the treatment of supracondylar femur fractures, and although there was no interlocking technique there was an improvement in the strength of the overall construct and a resisted tendency to varus [10].

Another important concept is that of 'toggle'. In the clinical situation bone screws are usually subjected to cyclical lateral loading which, over time, has been shown to reduce stability of a fixation and reduce screw pull-out strength [11]. This toggling occurs around a fulcrum which is the insertion point of the screw into the cortical bone. This has biological consequences of local osteoporosis and loosening which leads to a reduction in stability and ultimately mechanical failure. The use of the interlocked blade plate results in the formation of a triangular structure within the bone. This theoretically reduces 'toggle' and prevents loss of stability of the construct over time, preventing mechanical failure. This is particularly important in patients with poor bone stock.

These factors improve the stability in such fracture fixations, allow early mobilisation and improve the likelihood of the fracture healing before mechanical failure.

Whilst providing a sound mechanical purchase on the metaphyseal fragment the 'footprint' of the plate remains small. Obtaining an adequate fixation with multiple screws necessarily enlarges the contact area of a plate and the underlying area of periosteal compression further damages the blood supply to the already compromised bone.

The only complication in this study was impingement of the plate in a shoulder in one patient. This is a common complication in the fixation of proximal humeral fractures (15% in one series [12]). In our patient, it occurred partly because the entry point for the plate was too superior, but also because the DCP used to obtain the required solid fixation was quite bulky. If possible, a thinner plate should be used in these fractures (such as a one-third tubular plate) but the reduced strength of the fixation construct should be recognised [3].

6. Conclusion

The customised interlocked blade plate is an alternative for the fixation of metaphyseal fractures or nonunion in patients with poor bone stock. The quality of fixation is improved and the soft tissues are respected thereby allowing early mobilisation with fracture healing made more likely. The authors acknowledge that this modification to the DCP plate is not recognised by the manufacturers and the acuity of the plate bend must substantially weaken it for normal purposes. To date implant failure as a result of this has not occurred.

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