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Locked plate fixation for femoral shaft fractures

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Abstract Fifteen patients with a mean age of 31 years, who had sustained different types of femoral shaft fracture, were treated by locked plate fixation using standard AO dynamic compression plates (DCP). The fracture was open in five patients and ten had other significant injuries. Thirteen patients were available for follow-up at a mean period of 5 months (range, 3–10 months). All fractures united and the mean time to full weight bearing was 8 weeks. Screw failures, with breakage or bending, occurred in five patients and resulted in loss of alignment of the fracture in one. Nine patients regained a full active range of movement of the knee, two had an extension lag of 10° and two had restricted flexion. The strength of the quadriceps muscle was grade 4 to 5 in ten patients and grade 3 in the remaining three. At the end of the study period ten patients had returned to their normal activities, one used a walking stick and two remained under a rehabilitation programme. Our preliminary results suggest that locked plates may offer a useful alternative technique for the treatment of femoral shaft fractures.

Résumé Quinze malades d'âge moyen 31 ans présentant une fracture de la diaphyse fémorale ont été traités par plaque verrouillée utilisant une plaque de compression et des vis avec écrou bloquant. La fracture était ouverte cinq fois et dix malades avaient d'autres blessures associées. Treize malades ont été suivis en moyenne 5 mois. Toutes les fractures ont consolidé avec une reprise d'appui en moyenne à 8 semaines. Cinq fois les vis se sont rompues ou déformées avec, seulement dans un cas, une perte de réduction de la fracture. Neuf malades ont retrouvé une mobilité complète du genou. La force du quadriceps était cotée quatre ou cinq chez dix malades. Nos résultats préliminaires suggèrent que les plaques

verrouillées offrent une technique alternative utile pour le traitement des fractures de la diaphyse fémorale.

Introduction

Despite the wide application of intramedullary nailing in the treatment of femoral shaft fractures, there remain some indications for plate fixation. These may include patients with associated polytrauma, especially those with significant head or thoracic injuries [8, 18], ipsilateral femoral neck and shaft fractures [13], high subtrochanteric or supracondylar fractures [5], an excessively narrow medullary canal [15], and a laterally curved medullary canal, which is commonly associated with genu varum [16]. Plate osteosynthesis of diaphyseal fractures involves indirect reduction with careful extraperiosteal dissection to achieve axial and rotational alignment rather than anatomical reduction, with the minimal use of screws and by using a longer plate, in order to achieve optimal rather than absolute stability [11]. These concepts aim at maximising the biological reaction of the tissues to enhance fracture healing. However, since the stability of the plate depends upon the axial force of the screws compressing the plate to the bone, interference with the periosteal circulation causes cortical necrosis, which leads to cortical porosis beneath the plate, and this may adversely affect the healing potential of the bone with secondary loss of stability [11, 12]. However, with the new generation of plates (point contact fixator and locked plate), the stability of the construct depends upon the rigidity of the plate/screw interface rather than the high frictional forces at the bone/plate interface [6, 9]. This leads to minimal interference with the periosteal circulation, reducing stress shielding and improving the biological and mechanical performance of implants as shown by laboratory [1, 3, 7, 17] and some clinical reports [4, 14].

Based on these observations, the following is a preliminary report of the authors' experience in treating diaphyseal femoral fractures with locked plates using standard broad DCPs with locked screws.

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Materials and methods

The study involved 15 consecutive patients with diaphyseal fractures of the femur. All patients were male with a mean age of 31 years (range, 14–51 years). Most (13 cases) were caused by road traffic accidents, and ten had other significant injuries. The fractures were classified radiologically according to the AO classification [10], and clinically according to the Gustilo-Anderson grading [2]; five fractures were open (Table 1).

All operations were performed through a lateral approach with extra-periosteal dissection leaving a cuff of muscle of at least 5 mm covering the bone. No attempt was made to disrupt the clotted fracture haematoma or to expose the bone ends. It was possible by indirect reduction to restore length, axial and rotational alignment. A standard broad DCP was used with screws, which were locked into the holes of the plate by 4.5-mm nuts placed on the undersurface of the plate. A washer was placed between the nut and the plate for better locking. Two or three locked screws were used on either side of the fracture (Fig. 1).

Table 1 Fracture classification in 15 patients

	Number of patients
Gustilo's classification	
Closed	10
Open I	2
Open II	2
Open III	1
Total	15
AO classification	
Type A	6
Type B	7
Type C	2
Total	15

Fig. 1A–C Case 2, Table 2. **A** Pre-operative radiogram. **B** Post-operative radiograms, restoration of the length and alignment of the limb. **C** Eight weeks post-operatively, the fracture is united

Physiotherapy started on the second postoperative day with quadriceps exercises, and non-weight bearing continued until bridging callus was seen on the radiographs. Time to union of the fracture was defined as the time from surgery to radiographic maturation of the callus.

Results

The mean operating time was 75 min (range, 60–90 min). All patients received a blood transfusion of 500 ml during the procedure. Restoration of length, axial and rotational alignment was achieved in 14 patients; however, anatomical reduction was achieved in only one patient. There was malreduction with 5° of varus in one patient (case 7); the fracture, however, proceeded to union without functional disturbance. The mean follow-up of the 13 patients who were available was 5 months (range, 3–10 months). Two patients, who had moved, were lost to follow-up. Union was obtained in all 13 patients at a mean time of 8 weeks (range, 6–12 weeks; Table 2).

Screw failures with breakage or bending occurred in five patients. These were discovered at follow-up before the initiation of full weight bearing. The mean number of screws which failed accounted for half of the screws (one-sixth to two-thirds) used for fixation. However, this only resulted in fracture malalignment in one case (case 10), with resultant varus malunion of 15°. Screw failure occurred on both sides of the fracture in three cases, and usually involved the screws nearest to the fracture site. The incidence and number of screw failures could not be correlated to the radiological classification of the fracture. Nine patients regained a full active range of movement of the knee 3 to 4 months after surgery. Two patients had an extension lag of 10° which did not interfere with mobility. Two patients with persistent limitation of movement of the knee remained under a supervised reha-

Table 2 Data of the patients (*FU* duration of follow-up months, *ROM* degrees of range of motion)

Case	Age (years)	Fracture type		Associated injuries	Operative data		Time to union (weeks)	Complications	Status at the end of the study (FU)
		Gustilo	AO		Time (min)	Number of screws			
1	28	Open II	A	Bilateral forearm fractures	60	4	6		Returned to full activity (10)
2	42	Closed	B	Contralateral fracture femur ^a	75	6	8		Returned to full activity (8)
3	33	Closed	A	Fracture forearm bones	75	6	8	Failure of two screws	Returned to full activity (5)
4	42	Open III	B	Fracture scapula	90	6	10	Failure of four screws	Returned to full activity (5)
5	14	Closed	B	Ipsilateral fracture neck femur	60	6	8	Extension lag 10°	Returned to full activity (5)
6	16	Closed	B	Head injury, fracture mandible	60	4	6	Extension lag 10°	Returned to full activity (5)
7	35	Open II	C	Head injury, flail chest, rupture spleen	90	6	10	Failure of four screws	Returned to full activity (4)
8	19	Closed	A	Comminuted fracture distal radius, fracture ribs	75	6	6		Returned to full activity (4) (5° varus deformity)
9	20	Closed	B	Ipsilateral tibial plateau fracture	80	6	10	Stiff knee (ROM 10–80)	Under physiotherapy (4)
10	45	Closed	B	Ipsilateral sacro-iliac fracture dislocation	90	4	12	Failure of two screws ended in malunion 15°	Used cane (4)
11	25	Closed	A	Fracture maxilla, fracture olecranon	90	6	16		Returned to full activity (3)
12	28	Open I	B		60	6	18		Returned to full activity (3)
13	26	Open I	C		75	6		Lost to follow-up	
14	41	Closed	A		80	6		Lost to follow-up	
15	51	Closed	A		80	6	3	Failure of one screw Stiff knee (ROM 10–110)	Under physiotherapy (3)

^a Contralateral fracture femur treated by un-reamed interlocking nail

bilitation programme. At the end of the study, ten patients had grade 4 or 5 strength of quadriceps muscle, and three had grade 3. Ten patients returned to their original activities and one, with ipsilateral sacroiliac pathology and a malunited fracture, used a walking stick.

Discussion

Biomechanical and histological testing by many investigators has shown the superiority of point contact fixator (PC-Fix) over standard and limited contact DCP in the management of fractures [1, 3, 7, 9, 17]. Plates with nuts on the undersurface that lock the screws into the holes behave in the same manner as a PC-Fix [6]. As the plate is not in contact with the bone, cortical vascular disruption

is avoided, leading to better healing potential and possibly a lower infection rate [1]. The implant loses rigidity in its position away from bone, but through the locking nuts maintains adequate stability. This decreases bone resorption caused by stress shielding [6, 12]. The locking nuts allow the screw to reach a specific point without removing soft tissues at the fracture site, and can be used to create a fixed angle relationship between the screws and the plate. Kassab et al. [4] showed the effectiveness of locked plate fixation in a series of 44 patients with complex non-union or malunion. Similar results were reported by Ring et al. [14] in their group of patients with ununited fractures of the humerus.

Our results support the findings of these studies. Early union with bridging callus formation was seen in all types of fracture in our series, suggesting maximum

Fig. 2A–C Case 1, Table 2. **A** Post-operative radiogram of type A fracture, there is a lateral gap and a medial cortical defect together with non-anatomical reduction. **B** Four weeks after plating, there is early formation of callus that surrounds the fracture site. **C** At 12 weeks, solid union of the fracture

preservation of bone biology. In type A fracture, which carried the worst prognosis when treated by plating [15], union could be obtained with relatively stable fixation. This suggests that preservation of the cortical blood supply is important for the healing of this type of fracture following plating, even if previously recommended anatomical reduction and complete stability could not be achieved [11] (Fig. 2).

In contrast to the partially recessed spiked schuli nut with a bushing between the screw head and plate [4, 6], our technique uses the standard AO 4.5-mm nut with a washer placed beneath the plate. This does not prevent the screw head from gliding into the sloped oval hole of the plate, and maintains the dynamic compression function of the plate.

The problem of screw failure, which was seen in five patients, was attributed to the high load carried by the screws rather than the plate, as a result of the locking effect [6]. This is particularly true when there is premature locking of the screw before the nut is in contact with the bone, or if the screw is not inserted at the correct angle to the bone and plate, thus leaving a bare segment of the shaft of the screw between the nut and the bone. This only resulted in complications in one patient (Fig. 3); however, screw failure may necessitate early removal of implants. This problem may be solved by increasing the number of screws on each side of the fracture, or by increasing the stiffness of the screws which are used. It is possible that with the development of special nuts, with convex surfaces facing the bone and the plate, better distribution of stress would be obtained when the screw is inserted at an angle of less than 90° as is often required.

The disadvantage of this technique is that it involves an incision in the quadriceps muscle, which may extend postoperative rehabilitation. The size of the implant may also interfere with normal postoperative muscle function and would limit the use of this technique in fractures of subcutaneous bones, such as the tibia. The technique

Fig. 3 Case 7, Table 2. Immediate and 16 weeks post-operative radiograms of type C fracture. The four proximal screws are broken; however, the fracture united with no loss of the initial alignment apart from a few millimetres shortening

should be used with caution in subtrochanteric fractures, until stronger screws are developed.

Our preliminary results suggest that locked plates may offer a reliable technique in the treatment of femoral shaft fractures, and may offer an alternative to intramedullary fixation where there are contraindications to this form of treatment or if appropriate equipment is not available. Treatment with locked plates is also clearly cheaper. Further studies with larger numbers and longer follow-up are required to establish the place of this technique.

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References

1. Arens S, Eijer H, Schlegel U, Printzen G, Perren SM, Hansis M (1999) Influence of the design for fixation implants on local infection: an experimental study of compressing plates versus point contact fixators in rabbit. *J Orthop Trauma* 13:470–476
2. Gustilo RB, Anderson JT (1976) Prevention of infection in the treatment of one-thousand and twenty-five open fractures of long bones: retrospective and prospective analysis. *J Bone Joint Surg [Am]* 58:453–458
3. Jazrawi LM, Bai B, Simon JA, Kummer FJ, Birdzell LT, Koval KJ (2000) A biomechanical comparison of schuller nuts or cement augmented screws for plating of humeral fractures. *Clin Orthop* 377:235–240
4. Kassab SS, Jeffrey WM, Mayo KA (1998) Patients treated for nonunion with plate and screw fixation and adjunctive locking nuts. *Clin Orthop* 347:86–92
5. Kinast C, Bolhofner BR, Mast JW, Ganz R (1989) Subtrochanteric fractures of the femur. Results of treatment with 95° condylar blade plate. *Clin Orthop* 238:122–130
6. Kolodziej P, Lee FS, Patel A, Kassab SS, Shen K, Yang KH, Mast JW (1998) Biomechanical evaluation of the schuller nut. *Clin Orthop* 347:79–85
7. Koval KJ, Hoehl JJ, Kummer FJ, Simon JA (1997) Distal femoral fixation: a biomechanical comparison of the standard condylar buttress plate, a locked buttress plate, and the 95-degree blade plate. *J Orthop Trauma* 11:521–524
8. Marks PH, Kellam JF (1988) Heterotopic ossification around the hip with intramedullary nailing of the femur. *J Trauma* 28:1207–1213
9. Miclau T, Remiger A, Tepic S, Lindsey R, McIlff T (1995) A mechanical comparison of the dynamic compression plate, limited contact-dynamic compression plate, and point contact fixator. *J Orthop Trauma* 9:17–22
10. Müller ME, Allgöwer M, Schneider R, Willenegger H (1992) *Manual of internal fixation*. Springer, Berlin Heidelberg New York
11. Perren SM (1992) Basic aspect of internal fixation. In: Müller ME, Allgöwer M, Schneider R, Willenegger H (eds) *Manual of internal fixation*. Springer, Berlin Heidelberg New York
12. Perren SM, Cordey J, Rahn B, Gautier E, Schneider E (1988) Early temporary porosis of bone induced by internal fixation implants. *Clin Orthop* 232:139–151
13. Reimer B, Foglesong ME, Miranda MA (1994) Femoral plating. *Orthop Clin North Am* 25:625–633
14. Ring D, Perrey BH, Jupiter JB (1999) The functional outcome of operative treatment of un-united fractures of the humeral diaphysis in older patients. *J Bone Joint Surg [Am]* 81:177–190
15. Rozbruch SR, Müller U, Gautier E, Ganz R (1998) The evolution of femoral shaft plating technique. *Clin Orthop* 354:195–208
16. Said GZ, Hammam HM, Ibrahim AH (1973) Genu varum en Egypte. Problemes et relation avec la gonarthrose. *Rev Chir Orthop* 59:203–209
17. Tepic S, Remiger AR, Morikawa K, Predieri M, Perren SM (1997) Strength recovery in fractured sheep tibia treated with a plate or an internal fixator: an experimental study with a two-year follow-up. *J Orthop Trauma* 11:14–23
18. Wozasek G, Simon P, Redl H, Schlag G (1994) Intramedullary pressure change and fat intravasation during intramedullary nailing: an experimental study in sheep. *J Trauma* 36:202–207