Acta Orthop. Belg., 2008, **74**, 630-635

ORIGINAL STUDY

Locking plate construct for femoral shaft fractures in skeletally immature patients

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Different methods of internal fixation are used in the treatment of femoral shaft fractures. Results of locked plate fixation in adults have been encouraging. A locking plate construct with a standard broad Dynamic Compression Plate (DCP) and 4.5 mm nuts was used in the treatment of femoral shaft fractures in 15 skeletally immature patients. There were 12 boys and three girls. The mean age was 9.4 years at time of injury. Three fractures were open. All fracture healed in an average time of 8 weeks. The follow-up period ranged from 6 to 30 months (mean 18 months).

Screw failure in form of bending or breakage occurred in two patients, without clinical consequences. Fatigue fracture of the two screws in the proximal fragment occurred 15 weeks after fixation in another patient, which eventually healed with a 15° varus angulation. There was an average femoral lengthening of 2.3 mm in six patients and 2 mm of tibial lengthening in four patients. All patients returned to their pre fracture level of activity.

The locking plate construct used in this study appeared as a reliable method for the treatment of femoral shaft fractures in skeletally immature patients.

Keywords : femoral shaft fracture ; locked plate ; skeletally immature.

INTRODUCTION

Femoral shaft fractures account for 1-2% of all fractures before skeletal maturity. Boys sustain this injury 2.5 times more often than girls (*14,21*). Open reduction and plate fixation has been used to treat such fractures. The disadvantages of this method of treatment were related mostly to extensive periosteal stripping with subsequent cortical avascularity, bone atrophy under the plate, refracture and overgrowth (*12,20,27*).

Recently, a more biological method of reduction, named "indirect reduction", and new plate designs have been developed in an attempt to preserve the blood supply to the injured bone, improve the rate of fracture healing, decrease the need for bone graft and the incidence of infection (*16,28*).

However, with the new plate generation, "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 (*19,24*). This leads to minimal interference with the periosteal circulation, which reduces the stress shielding and improves both biological and mechanical performance of

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No benefits or funds were received in support of this study

Table I. — Mechanism of injury

Mechanism of Injury	No (%)	Associated injuries
Fall from height	7 (46.7)	2
Motor car accident	4 (26.7)	3
Run over accident	2 (13.3)	1
Sports injury	2 (13.3)	0
Total	15 (100)	6

the implant as shown by laboratory and clinical reports (*2,18*).

The published results of locked plate fixation using standard broad DCP with locked screws for both fresh and non-united femoral shaft fractures have been encouraging (*1,5*).

We report the results of locking plate construct fixation in fresh femoral shaft fractures in skeletally immature patients.

MATERIAL AND METHODS

Fifteen skeletally immature patients with femoral shaft fractures were included in this study. There were 12 boys and three girls. The ages ranged from 7 to 13 years (mean : 9.4 years). Almost 75% of the patients were injured as a result of either a fall from a height or a motor car accident (table I). Twelve fractures were closed and three were open. The open fractures were grade II according to the classification of Gustilo and Anderson (*10*).

Six patients had eight associated injuries. Head injuries were present in three patients ; one had a ruptured spleen and another patient had a non displaced ipsilateral fracture of the surgical neck of the humerus. Two patients had a displaced diaphyseal forearm fracture and one patient had a slipped ipsilateral lower tibial epiphysis.

The time elapsed from injury to surgery ranged from one to nine days (average 3.9 days).

All operations were performed under general anaesthesia through a lateral approach with extraperiosteal dissection leaving a thin cuff of muscle covering the bone. All possible efforts were made to minimise the exposure of the fracture ends in closed fractures. Restoration of length, axial and rotational alignment was achieved. A standard broad DCP was used with 4.5 mm cortical screws locked into the plate holes by 4.5 mm nuts placed on the undersurface of the plate. At least three locked screws were used on either side of the fracture.

Static quadriceps exercises were started from the second postoperative day. Non-weight bearing with two crutches was started from the second week and was progressed to partial weight bearing as tolerated. Full weight bearing was allowed when bridging callus was obvious on radiographs. The time to union was defined as the time from surgery to radiographic maturation of the callus. At the last follow-up, a scanogram was done to evaluate the leg length.

RESULTS

The mean operating time was 80 minutes (range : 60 to 100 minutes). Six patients received one unit of blood during surgery. Anatomical reduction was achieved in all patients. Intra fragmentary screws across the fracture site were used in three patients. The average follow-up period was 18 months (range : 6 to 30 months). All fractures were united in a mean time of 8 weeks (range : 6 to 12 weeks).

Screw failure, either bending or breakage, occurred in two patients during the period of partial weight bearing. Both patients had the proximal screw adjacent to the fracture broken with bending of the second proximal screw in one of them. Full weight bearing was delayed with no deleterious effects on either union or alignment.

In another patient, fatigue fracture of the two screws in the proximal fragment occurred 15 weeks postoperatively, before the fracture was healed, resulting in a 15° varus angulation at the fracture site. The family refused surgery and the boy was managed by a spica cast for six weeks till union with no obvious clinical deformity (fig 1). The implant was subsequently removed. The boy is now reaching skeletal maturity ; he is participating in all activities with no complaint regarding the residual radiological deformity.

Thirteen patients regained a full range of motion whereas the other two lost the last 20° of flexion, at 10 and 22 months after surgery respectively. We had an average femoral lengthening of 2.3 mm in six patients (range : 1 to 6 mm). Also, an average tibial lengthening of 2 mm (range : 1 to 3 mm) was found in four patients (table II).

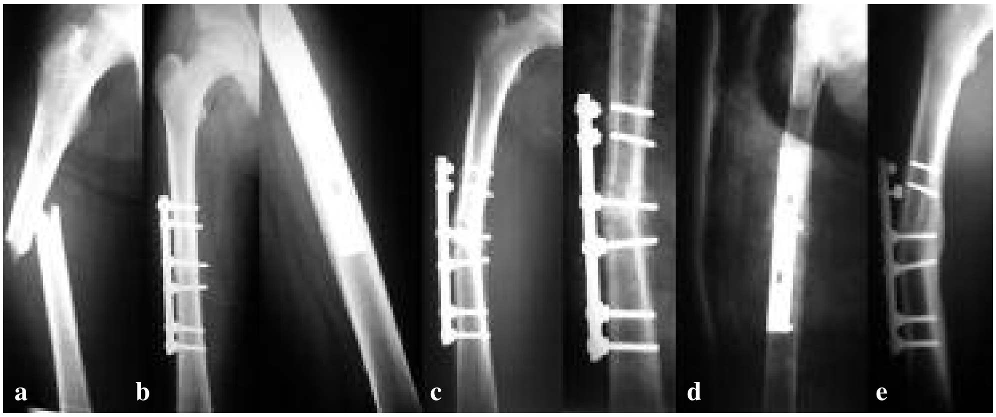

Fig. 1. — Mid-shaft fracture of the right femur. a : preoperative radiograph ; b : AP and lateral view following fixation with a locked plate ; c : follow-up radiographs showing breakage of the proximal screws with loss of fixation and varus angulation at the fracture site ; d : the limb was imobilised in a spica cast ; e : the fracture healed with fair alignment.

Table II. — Complications

Complications	No
Femoral lengthening(average 2.3 mm)	6
Tibial lengthening (average 2 mm)	4
Screw failure (either bending or breakage)	2
Loss of last 20 degrees of knee flexion	2
Refracture with residual varus	1

Quadriceps muscle was grade 5 in all patients. All patients returned to their pre-fracture level of activity and participated freely in recreational activities (fig 2).

DISCUSSION

There are many different surgical treatment alternatives for femoral shaft fracture in children. It is not possible to accurately prove that one surgical technique is superior to another. Internal fixation techniques have been modified over the last decades to improve fracture healing. The new plating methods seek to minimize exposure of the fracture site and devascularisation of the fractured bones (*8*).

The superiority of a point contact fixator (PC-Fix) over a standard and limited contact DCP has been demonstrated by biomechanical and histological testing (*2,15,19,24,27*).

The construct used in this study is essentially based on a threaded washer, serving two purposes : it allows screws to lock to the plate, therefore preventing screw toggle and stripping in the bone as the screw is advanced ; it also limits the contact of the plate with the underlying bone in an attempt to preserve periosteal perfusion, which leads to better healing, lower infection rate and decrease of bone resorption caused by stress shielding (*2,11*). This achieves a fixed-angle or “locked” internal fixation construct that behaves in the same manner as a PC-Fix (*8,11,18*).

Kolodziej *et al* (*18*) have shown that locking the screws improved the stability of the construct. Kassab *et al* (*17*) and Ring *et al* (*26*) showed the effectiveness of a locked plate fixation in both complex non-united and malunited fractures.

Good results were reported by using the same locking construct in both recent and non-united fractures in adults (*1,5*).

The problem of screw failure with the construct used may be attributed either to the high load applied to the screws (*18*), to premature locking before the nuts get in contact with the bone (*5*), or to the fact that screws were not inserted in the correct angle to the bone or the plate which leaves a bare segment of screw between nut and bone (*2,5,18*). This problem could be addressed by increasing the number of screws on each side of the fracture or by using screws with increased stiffness. Special nuts

Fig. 2. — Grade II open fracture of the left femur. a : preoperative AP and lateral view ; b : following fixation with a locking plate construct, primary fracture union was achieved.

with a convex surface facing the bone would be of great help as it would allow for a better load distribution when screws were inserted in the correct angle as always required (*5*). Abdel-Aal *et al* (*1*) used two locked screws on each side of ununited fractures in adults and achieved excellent results in all of their patients.

In this study, at least three locked screws were used on each side of the fracture and this explained the lower incidence of screw failure compared with similar studies (*1,5*). We had screw failures in two of our patients, which occurred early in the study. These screws were inserted at less than 90° angle to the long axis of the bone, which increased the load applied to them, with subsequent failure. The direction of screw insertion was improved along with the learning curve, which minimized this complication later on in the study.

Mann *et al* (*23*) reported good results with Ender nails. Ligier *et al* (*22*) believe that Ender nails are insufficiently elastic for children's fractures, with a tendency to straighten the normal bony curvature.

Flynn *et al* (*9*) reported excellent results in children treated with elastic nailing. Narayanan *et al* (*25*) reported an incidence of 70 complications in 78 patients treated with elastic nailing. They reported 41 patients with pain or irritation at the nail insertion site, malunion in 8 patients, loss of reduction in 5 patients, refracture in two patients, nerve deficit in two patients, superficial wound infection in another two and ten patients required reoperation prior to union. These figures may reflect the possible high morbidity with the use of this technique.

Good results were reported with external fixation, but with a high rate of complications. Hedin *et al* (*13*) reported that almost all patients treated with an external fixator healed with some angulation. They further reported pin track infection in 36% of patients, refracture in two patients and repeat reduction was required in 15%. Three children developed a slowly progressive bending at the fracture site during the first month after removal of the fixator, making a corrective osteotomy necessary.

The ability of a child's femur to overgrow is a well known phenomenon. It has been shown that femoral overgrowth occurs more frequently with plate fixation than with other methods of treatment (*7*). Overgrowth is caused by activation of the growth plate in some way. Extensive dissection and periosteal stripping during plate application may impair fracture healing or may lead to overgrowth (*4*). Eren *et al* (*6*) had an average lengthening of 12 mm on the operated side in 13 out of 24 patients who had their plates removed. Only two patients out of ten, who retained their plates had overgrowth. They assumed that avoiding a second periosteal trauma may decrease growth stimulation. Kregor *et al* (*20*) reported an average femoral lengthening of 9 mm and tibial lengthening of 4 mm. Hansen (*12*) reported a mean overgrowth of

7 mm (range -9 to 25 mm) in patients followed up to skeletal maturity. Bopst *et al* (*3*) noted overgrowth in 43.5% of children treated with elastic nailing and it was more than 1 centimeter in 8.2% of them.

The mean overgrowth in this work is quite less than reported with conventional plate fixation ; this may be explained by the minimal periosteal trauma during application or removal of the locking construct. Follow-up of these patients until skeletal maturity is recommended to prove this.

The average healing time of the study group is comparable to other studies using different treatment modalities (*3,6,9,12,28*).

Our results suggest that this method is a reliable option in skeletally immature patient. It offers some form of biological fixation with no need for special equipments such as a fracture table or an image intensifier as required in medullary nailing, external fixation or percutaneous plating.

Also, this method of treatment is cheap, compared to elastic nails, external fixators or commercially available locking plates, which makes it more suitable in our country.

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