Y. S. Choi · K. S. Kim

Plate augmentation leaving the nail in situ and bone grafting for non-union of femoral shaft fractures

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Abstract We reviewed 15 patients with femoral non-union after interlocking intramedullary nailing treated with plate augmentation and bone grafting with the nail in situ. The mean time from primary nailing to plate augmentation and bone grafting was 10 months. At the time of presentation, the patients had undergone an average of 1.6 operations from the time of their original injury. To achieve stability of the fracture, we applied an AO plate on the lateral aspect of the femur. The retained nail maintained alignment of the fracture, and plating did not require an extensive surgical approach. In all patients, there was visible motion at the fracture site; however, the motion disappeared after plate augmentation. All patients achieved radiological solid union at an average of 7.2 months.

Résumé Nous avons suivi 15 malades avec une pseudarthrose fémorale après enclouage centromédullaire traitée avec une plaque supplémentaire et une greffe osseuse en laissant le clou en place. Le délai moyen entre l'enclouage initial et la reprise chirurgicale avec plaque et greffe était de 10 mois. Au moment de l'étude les malades avaient subi une moyenne de 1,6 opérations à dater du traumatisme. Pour obtenir la stabilité de la fracture, nous avons utilisé une plaque externe AO. Le clou laissé en place a maintenu l'alignement de la fracture et la mise en place de la plaque n'a pas exigé un abord chirurgical étendu. Chez tous les malades il y avait une mobilité du foyer de fracture qui a disparue après l'ostéosynthèse par la plaque. Tous les malades avaient une consolidation radiologique solide à une moyenne de 7,2 mois.

Introduction

Currently, there are several options in the treatment of femoral non-union after intramedullary nailing: reamed exchange nailing [5, 6, 13], dynamization [16], nail removal followed by plating [2], stable fixation with or without bone grafting [3, 11, 12], and external fixation [9]. Reamed exchange nailing results in few complications, does not require bone grafting, and offers the benefit of early rehabilitation. However, the reported rate of bony union after reamed exchange nailing varies from as high as 100% by Klemm [8], to 78.3% by Hak et al. [6], and as low as 53% by Weresh et al. [15]. A better understanding of the mechanics of fracture stabilization and of the biological requirements for fracture healing has improved the outcome in these difficult cases [1].

Plate augmentation leaving the nail in situ provides stability of the fracture when there is continuous excess motion at the fracture site after interlocking intramedullary nailing. The retained nail acts as a useful load-sharing device, neutralizing the shear forces on the non-union site [9] and maintaining alignment of the fracture. Plate augmentation leaving the nail in situ does not require an extensive surgical approach to the bone, as does the conventional plate technique. We performed plate augmentation and bone grafting leaving the nail in situ in 15 patients in whom more stability was required than that provided by interlocking intramedullary nailing. The objective of this study was to evaluate the outcome of such treatment.

Materials and methods

Between January 1995 and August 2001, we treated 32 patients with non-union of femoral shaft fractures after interlocking intramedullary nailing. Among these patients, 15 had continuous motion at the fracture site, which we judged would not improve following a reamed exchange nailing (Fig. 1). These patients therefore underwent plate augmentation and bone grafting leaving the nail in situ.

Y. S. Choi (✉) · K. S. Kim
Department of Orthopedic Surgery,
Kwangju Christian Hospital,
264 Yangrim-dong, Namgu,
Gwangju, South Korea, 503-715
e-mail: stemcellchoi@hanmail.net
Tel.: +82-62-6505064
Fax: +82-62-6505066

Fig. 1 **a** An 18-year-old man with comminuted femoral shaft fractures treated with interlocking intramedullary nailing. **b** Six months after initial operation, the nail was exchanged to a larger one after reaming; 10 months after exchange nailing, there was still a gap of the fracture and loose distal locking screw. **c** Plate augmentation and exchanging distal locking screw was performed to provide stability, and bone graft was done to promote union; 8 months after plate augmentation, a bony union was obtained without complications

There were 12 men and 3 women. Mean follow-up period after plate augmentation and bone grafting was 42.3

(range: 22–60) months. Average age at the time of injury was 36.8 (range: 18–61) years. The initial injury mechanism was motor vehicle accidents in 14 cases and a fall in one. The shaft was defined as the part of femur located between 5 cm distal to the lesser trochanter and 5 cm proximal to the adductor tubercle. In ten cases, the fracture site was located in the mid femoral shaft and in five cases in the distal third. The type of comminution was graded according to Winquist–Hansen. There were two cases of type I, five of type II, five of type III, and three of type IV. Four cases were open fractures. Associated injuries were present in 11 cases. Interlocking intramedullary nailing was performed to treat femoral shaft fractures at our hospital and at other facilities an average of 4.5 (range: 1–9) days after the initial injury. All fractures were originally treated with statically locked antegrade intramedullary nails, ten of which were placed after reaming of the medullary canal and five of which were placed using an unreamed technique. At the time of presentation, these cases had undergone between one and three previous operations (mean: 1.6) from the time of the initial injury. A nonunion was defined by persistent pain at the fracture site combined with the absence of progressive healing on three consecutive radiographs taken at 1-month intervals or failure to unite at 6 months after surgery. According to the classification by Weber and Brunner [14], the non-union was hypertrophic in one case and oligotrophic in 14 cases. Thus, we believe that the most important factor for failure to unite was instability at the fracture site. Plate augmentation and bone grafting was done at an average of 10 (range: 8–15) months after the primary procedure (Table 1).

The non-union site was exposed through a posterolateral approach, and an AO plate was applied to the lateral aspect of the femur. The retained nail maintained alignment of the fracture. The plating did not require excessive devascularisation of the bone or the soft tissue envelope. Screws were fixed at the proximal and distal parts of the femur bicortically, when possible, and cancellous bone grafts were placed around the fracture. An average of five (three to nine) cortices were purchased with the screw in the proximal fragment and six (three to eight) cortices in the distal fragment. Four cortices for augmentation in the upper and lower portions of the fracture were often enough to correct the instability because of the interlocking intramedullary nail remained in situ. Although there was visible motion at the fracture site in all cases before plate fixation, the movement disappeared after plate augmentation.

Patients were allowed knee-joint exercise and partial weight bearing with the aid of crutches immediately after surgery without external supports or devices. Full weight bearing was allowed 3–5 months postoperatively when bony union had been achieved clinically.

All patients were examined at prearranged intervals for 1 year: once every four weeks until radiographic consolidation and then at intervals of 3 and 6 months. We monitored the range of knee motion and the progress of bony union during the follow-up. Bony union was achieved when local tenderness at the non-union site had disap-

Table 1 Summary of patients

No.	Age	Sex	Site	W-H Class.	Injury type	Type of nonunion	No of Op	Nonu (M)	Op time (min)	Bl Loss (ml)	Cl union (M)	Rad union (M)	F/U (M)
1	21	M	Distal	III	open	oligotrophic	3	15	50	150	5	11	48
2	46	M	Middle	IV	closed	oligotrophic	1	15	70	300	3	5	33
3	18	M	Middle	III	open	hypertrophic	2	10	110	250	3	8	40
4	40	M	Middle	IV	closed	oligotrophic	1	12	60	300	5	9	60
5	21	M	Middle	II	closed	oligotrophic	2	8	50	150	4	5	58
6	45	M	Middle	II	open	oligotrophic	2	8	50	200	5	9	30
7	36	M	Middle	III	closed	oligotrophic	1	12	70	300	3	9	23
8	29	M	Middle	I	closed	oligotrophic	1	13	50	150	4	8	57
9	57	M	Middle	III	open	oligotrophic	3	10	100	300	4	5	55
10	61	M	Distal	II	closed	oligotrophic	2	10	60	200	4	8	46
11	33	M	Distal	II	closed	oligotrophic	1	8	70	300	3	7	22
12	23	M	Middle	I	closed	oligotrophic	2	14	50	250	4	7	34
13	25	F	Middle	II	closed	oligotrophic	1	3	60	200	5	8	40
14	41	F	Distal	IV	closed	oligotrophic	1	5	75	300	3	8	48
15	46	F	Distal	III	closed	oligotrophic	1	7	70	200	3	7	41

W-H Winquist-Hansen, *Class* classification, *No of Op* number of operation, *Nonu* Duration of Nonunion, *M* Months, *Op time* operation time, *Bl Loss* blood loss, *Cl union* clinical union, *Rad union* radiological union *F/U* the length of follow up after plate augmentation

Fig. 2 **a** A 21-year-old man with non-union of a distal-third fracture of the femur that was treated with plate augmentation at 15 months after initial operation. **b** Eleven months after plate augmentation, radiographs revealed the screws were loosened; but 36 months after the last operation, bony union was obtained without complications, and removal of the interlocking nail was done

peared, when full weight bearing was possible without pain, and when the fracture line was bridged by callus and closed by more than 3/4 radiologically.

Results

For plate augmentation and bone grafting, the time of operation was an average of 66.3 (50–110) min, mean blood loss was 237 (150–300) ml, and there were no complications during the procedures. In all patients, the range of knee and hip motion did not decrease post-operatively. Pain and/or tenderness around the fracture site improved in an average of 3.9 (range: 3–5) months after the operation. Radiological bony union was achieved in all patients in 7.2 (range: 5–11) months without further surgical intervention. In one patient in whom screw fixation was performed with three cortices in the upper and lower portion of the fracture (Fig. 2), the screws became loose. Radiographs indicated that bony union was achieved.

Discussion

Those patients in whom a plate was added in the presence of a nail were monitored closely for vascular insufficiency at the fracture site because we were concerned about the biological aspects of fracture healing. No clinical problems were observed. Conventional stable plate fixation with precise reduction usually requires a fairly extensive surgical approach to the femur and has a high complication rate including infection, high intraoperative blood loss, and higher non-union rates than interlocking intramedullary nailing [18]. However, plate augmentation in these 15 patients did not require extensive dissection of the bone since the retained nail maintained the alignment of the fracture. According to Cole's study [4], the blood supply recovered

within 2 weeks of surgery in all cortical areas, including the periosteal and the endosteal area, after the insertion of a reamed or unreamed nail. Wolinsky et al. [17] reported that blood supply would be recovered by 6–12 weeks post-operatively. We therefore believe that problems related to insufficient blood supply of the fracture will not arise if sufficient time is allowed to pass between each procedure.

Reamed exchange nailing remains the treatment of choice for the non-union of femoral shaft fractures but a significant number of patients who undergo reamed exchange nailing require additional procedures to achieve fracture healing [4, 15]. Although interlocking screws can increase the rotational resistance, the rotational stiffness of an interlocking nail is only 3% compared to 55–70% of bending stiffness of the normal femur according to Johnson et al. [7]. Furthermore, according to these experiments, the fracture site did not show much resistance to rotational movement within a 10–15° angle when an interlocking intramedullary nail was inserted, suggesting that the absolute fixation power at the fracture site by an interlocking intramedullary nail, especially against rotational force, is limited. Intramedullary nails in distal shaft or comminuted fractures of the femur are also not canal-filling which reduces stability in bending and rotation. Too much motion in those complex fractures results in unpredictable mechanical strength and some non-union [10]. This small subset of cases may require more stability than that is afforded by interlocking intramedullary nailing [6].

Ueng et al. [12], as in our study, reported successful bony union with plate augmentation in the presence of intramedullary nail for femoral non-union. However, in contrast to Ueng et al., cancellous bone graft obtained from the antero-superior iliac crest was applied over the non-union site at the time of plate augmentation in all 15 of our patients to fill the bony defect and to stimulate fracture healing.

Although this study is limited by the small cohort of patients and the lack of a control group, it demonstrates that plate augmentation and cancellous bone grafting leaving the nail in situ can be an effective solution in cases of unstable femoral non-union after interlocking intramedullary nailing.

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