Evaluation of static locked intramedullary nailing for treatment of comminuted femoral shaft fractures

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Background

The treatment of femoral shaft fractures has always been a focus of interest, but until now has remained a clinical problem and a subject of controversy. The aim of this work was to evaluate the role of static interlocked nailing in the treatment of a comminuted fracture of the femoral shaft in our initial cases managed by this technique at Al-Azhar University Hospitals.

Patients and methods

The results of treatment of comminuted fractures of the femoral shaft with static interlocking nailing were reviewed retrospectively in 60 patients. Ten of them had bilateral fractures, which allowed 70 fractures to be reviewed.

Results

All managed fractures (100%) had healed without conversion to dynamic intramedullary fixation. No broken nails were detected. At the final postoperative follow-up evaluation according to Thoresen and colleagues, we obtained excellent and good results in 65 (92.85%) femoral fractures, fair results in five (7.15%) femoral fractures, and no (0%) poor result. We had 100% fracture union in all cases with a mean time of eight postoperative months.

Complications

Only one (1.4%) patient had deep infection. Eight (11.4%) patients had pulmonary embolism, which was the major cause of morbidity associated with bed recumbence in our study.

Conclusion

We concluded that this method of treatment — static intramedullary nailing fixation — for comminuted shaft fractures of the femur is an effective method that maintains the length and alignment, with a low incidence of complications.

Keywords:

comminuted femoral, intramedullary nailing, static locked femoral nail

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Introduction

Femur is the longest, strongest, largest, and heaviest tubular human bone. Femoral shaft fractures are common among adults because of vulnerability to road traffic accidents (RTAs), fall from a height, industrial accidents, or firearm injuries; hence, these fractures are commonly caused by high-energy force mechanisms and are often associated with multisystem trauma [1].

Femoral shaft fractures can lead to a major physical impairment, not because of disturbed fracture healing but because of fracture shortening, fracture malalignment, or prolonged immobilization of the extremity by traction or casting in an attempt to maintain the fracture length and alignment during the early phases of healing. Even minor degrees of shortening and malalignment may result in a limp and in post-traumatic arthritis. The art of femoral fracture care is a constant balance between the often conflicting goals of anatomic alignment and early functional rehabilitation of the limb [2–4].

The treatment of femoral shaft fractures has always been a focus of interest, but until now has remained a clinical problem and a subject of controversy. Several techniques have been developed for the treatment. Operative treatment in the form of plating, nailing, and external fixation is still being carried out for these fractures in many parts of the world.

Closed reduction and intramedullary nail fixation, as has been proposed by Küntscher and Fischer [5], is the most biological way of treating fractures of the femoral shaft. Kempf *et al*. [6] introduced the locked intramedullary nail for the treatment of comminuted fractures of the femur. They reported that this method gave axial, rotational, and bending stability to the fracture, with low incidences of infection, nonunion, and malunion. The indications of intramedullary fixation of fractures of the femoral shaft have been greatly expanded by techniques of interlocking nailing since then [7,8]. Many investigators have been concerned that static interlocking nailing might interfere with fracture healing because of the decreased loads across the site of a fracture that has been treated with this type of fixation.

However, postoperative fixation failure by dynamic intramedullary nailing in terms of maintenance of reduction of the fracture, shortening, and rotation reported by Brumback *et al.* [2] prompted us to use static interlocking nailing for the treatment of all fractures of the femoral shaft, regardless of the degree of comminution or the location of the fracture.

Static interlocking nailing describes the interlocking construct in which both proximal and distal interlocking screws are inserted. Shortening and malrotation are controlled by transferring the axial and rotational stresses through the nail rather than through the site of the fracture [9].

The aim of this work was to evaluate the role of static interlocked nailing in the treatment of comminuted fractures of the femoral shaft in our initial cases managed by this technique at Al-Azhar University Hospitals.

Patients and method

We reviewed retrospectively the medical records and radiographs of all patients who had acute, fresh metaphyseodiaphyseal comminuted fractures of the femoral shaft that had been treated with static interlocking nailing and had been maintained until fracture united with a minimum duration of follow-up of 1 year postoperatively between January 2006 and December 2009 at Al-Azhar University Hospitals. There were 60 patients. Ten of them had bilateral fractures, which allowed 70 fractures to be reviewed. Any patient younger than 16 years of age or had a pathological fracture, trochanteric fracture, old fracture, or refractures were excluded from this study.

The duration of follow-up ranged from 12 to 24 months with a mean of 15 months. The age range was from 16 to 63 years with an average age of 33 years (Table 1). Male patients were 53 (90%) and female patients were seven (10%) in number (Table 2).

Technique

All patients were operated upon using the same technique with the patients positioned laterally on the fracture table. The mean time from admission to operation was 7 days (Table 3). Patients were given either spinal or general anesthesia. The method of interlocking nails was close or open femoral nailing under an image intensifier (Table 4). The type of nailing was antegrade interlocking nails.

After reduction, the entry point was through the piriformis fossa using awl, and then a guidewire was introduced into the medullary canal and across the fracture site under image control. This was followed by reaming with a power drill using flexible intramedullary reamers that were then used to increase the diameter of the canal in 0.5 mm increments in a stepwise manner to 1 mm more than the nail size to be used (Table 5). With the appropriate nail inserted in its suggested place, a special jig was used to introduce the proximal locking screw. The distal screws were then placed percutaneously by free-hand technique under C-arm control.

The postoperative follow-up policy was to allow partial weight bearing as tolerated within the second or third postoperative day for 8–12 weeks when radiographs showed sufficient bridging callus; it was then gradually increased to full weight bearing.

The patients were followed up at regular intervals every 2 weeks after discharge for the first 2 months, and then monthly for 1 year and every 6 months in the second year. Minimum follow-up was 12 months and the maximum was 24 months. Healing of the fracture was characterized by bridging callus seen on two radiographs taken with different projections.

Hospital stay

The mean hospital stay was 17 days, ranging from a minimum of 6 days to a maximum of 82 days. The mean preoperative period was 6 days.

Table 1 Age distribution

	Age groups (years)				
	16–25	26–35	36–45	46–55	56+
Number of patients (%)	15 (25)	30 (50)	10 (16.67)	3 (5)	2 (3.33)

Table 2 Sex and side distribution

	%
Male	90
Female	10
Unilateral	39 (left); 44.4 (right)
Bilateral	16.6

Table 3 Duration (hospital stay) from date of admission to date of operation

Within 24 h (%)	24–48 h (%)	48–72 h (%)	4–9 days (%)	>10 days (%)
2 femurs (2.9)	7 femurs (10)	13 femurs (18.5)	42 femurs (60)	6 femurs (8.6)

Table 4 Method of reduction used

Closed reduction (%)	Open reduction (%)
56 femurs (80)	14 femurs (20)

Table 5 Nail dimensions used

Diameter (%)	9 (15.7)	10 (37.1)	11 (44.3)	12 (2.9)	—	—
Length (%)	34 (2.9)	36 (4.2)	38 (20)	40 (50)	42 (20)	44 (2.9)

Classification

The incidence of fracture in different parts of the femur is shown in Table 6. Comminution of the fractures was graded according to the Winquist–Hansen classification [10,11], which is based on the percentage of intact circumferential cortical contact of the major fragments. According to the Winquist classification (Table 7) type I fracture was seen in 15 (21.4%) operated femurs, type II fracture was seen in 20 (28.6%) operated femurs, type III in 19 (27.15%) operated femurs, and type IV in 16 (22.85%) operated femurs.

Fracture union was evaluated both clinically and radiologically, and graded at 12 months after treatment following Thoresen's criteria (Table 8) [12].

Treatment outcome was analyzed regarding fracture healing, joint movements, and implant failure. For this purpose, these patients were postoperatively followed up at intervals of 2 weeks, 6 weeks, 3 months, and then monthly thereafter, regularly for a total of 24 months. Patients were discharged as soon as their condition allowed. The criteria of classification were applied as proposed by Thoresen *et al.* [12], with the addition of nonunion at 12 months or nail breakage as criteria for a poor result (Table 8). The outcome results regarding fracture union at 12 months were graded as excellent, good, fair, and poor. Clinical criteria of union included absence of pain and local tenderness on stressing the fracture site or full weight bearing of the operated limb. Radiological healing of the fracture was defined as the presence of callus around the fracture circumference with density similar to that of the adjacent cortex, or obliteration of the fracture line, whichever was earlier. Healing of the fracture was considered complete when both clinical and radiological criteria of union were fulfilled to the satisfaction of the authors and the independent observer. Delayed union was recorded when the fracture united between 4 and 6 months, whereas nonunion was noted when union had not occurred after 8 months of treatment. All of our patients were followed up for at least 12 months.

Clinical criteria of union included absence of pain and local tenderness on stressing the fracture site or full weight bearing of the operated limb. Radiological healing of the fracture was defined as the presence of callus around the fracture circumference with density similar to that of the adjacent cortex, or obliteration of the fracture line, whichever was earlier.

Healing of the fracture was considered complete when both clinical and radiological criteria of union were fulfilled to the satisfaction of the authors and the independent observer.

Results

The mode of injury found was RTAs in 88% and fall from a height in 9% of patients; pedestrians accounted for 3% of injuries. Associated injuries occurred in 35 (50%) patients Tables 9 and 10).

The clinical outcome showed that all (100%) patients had union at 8 months. The average time for union was 3 weeks. One patient had deep infection. This patient was a 43-year-old man admitted with fracture of the right femoral shaft. He was operated upon on the same day of admission. Two months later the patient developed symptoms and signs of infection. He was then operated upon under general anesthesia; debridement and irrigation was carried out. Systemic antibiotics after culture and sensitivity test were given to the patient until all symptoms and signs of infection had resolved. By follow-up evaluation we found that the fracture had united at 8 months postoperatively.

Table 6 Fracture site distribution

Upper third	Middle third	Lower third	Segmental	Combination
12	41	7	5	5

Table 7 Fracture classification according to Winquist–Hansen

Type	0	1	2	3	4
Number	0	15	20	19	16

Table 8 Criteria for classification of results (modified from Thoresen *et al.* [12])

Criteria	Results			
	Excellent	Good	Fair	Poor
Malalignment of femur (deg.)				
Varus/valgus	0	5	10	>10
Antecurvatum/recurvatum	5	10	15	>15
Internal rotation	5	10	15	>15
External rotation	10	15	20	>20
Shortening of femur (cm)	1	2	3	>3
Knee motion (deg.)				
Flexion	>120	120	90	>90
Extension deficit	5	10	15	>15
Pain/swelling	None	Minor	Significant	Sever
Nonunion/nail breakage	Absent	Absent	Absent	Absent

Table 9 Mode of trauma

RTA (%)	Fall from height (%)	Pedestrian (%)
88.33	8.33	3.33

RTA, road traffic accident.

Table 10 Associated injury and/or chronic illness

Head injury	Chest injury	Abdominal injury	Other bony injuries	Associated medical condition-(DM, obesity, ischemic heart diseases)
8	5	5	17	10

DM, diabetes mellitus.

Abductor weakness resulting in Trendelenberg gait was observed in one patient even after 3 months of nail removal. Four patients had limited range of motion in the knee joint. There were no cases of significant malrotation, axial shortening, or lengthening.

No dynamization was done in any of the cases. Static interlocking nailing was performed in all patients. Closed nailing was accomplished in 80% of the patients. In the remaining 20%, open reduction was necessary because of failure to pass the guidewire across the site of fracture under fluoroscopic control.

The mean time to union was found to be 16 weeks (when adequate radiographic callus was visible). All fractures united well.

Eight (13.3%) patients had developed pulmonary embolism, which was a major cause of morbidity associated with bed recumbence.

There was proximal screw breakage in two patients and distal screw breakage in four patients.

At the last follow-up the average flexion of the hip was 100° (range 80–135°). No patient had a fixed flexion contracture of the knee. The patients with less than 90° of flexion of the knee were those with fracture of the ipsilateral tibia (12 patients).

In three patients who had a comminuted fracture of the distal third of the femur, an angular malunion developed, meaning that there was more than 5° of varus or valgus angulation at the site of the fracture. These fractures were treated with an interlocking nail, but the distal location permitted placement of only one locking screw. Loss of reduction occurred in all three patients. None of them needed an additional operation, but a supracondylar femoral osteotomy was planned for one of them. This patient had a varus malunion.

Three patients had a limb length discrepancy of less than 2 cm, but it was not associated with any functional impairment. No reconstructive operation was performed in any of these patients.

The clinical/radiological evaluation was performed at the final follow-up at a minimum of 12 months postoperatively and the final observations were made according to the criteria by Thoresen *et al.* [12]. We obtained excellent results in 58 (82.85%) patients, good in seven (10%), fair in five (7.14%), and no (0%) poor result.

The majority of patients complained of pain at the fracture site and knee, which was treated with analgesia. Overall, 22 complications were detected and were classified as: general complications, local complications, and complications related to the implant (Tables 11–13 and Figs 1–3).

Table 11 General complications

Complications	Number of patients (%)
Pulmonary embolism	8 (13.33)

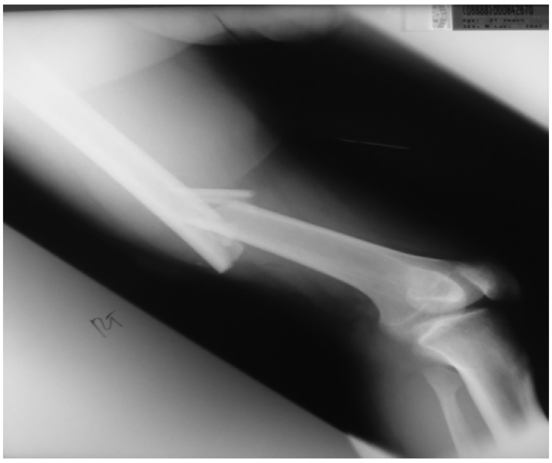
Table 12 Local complications

Complications	Femur operated (%)
Deep infection	1 (1.4)
Knee limitation of range of motion	4 (5.7)
Malunion	3 (4.3)

Table 13 Complications related to the implant

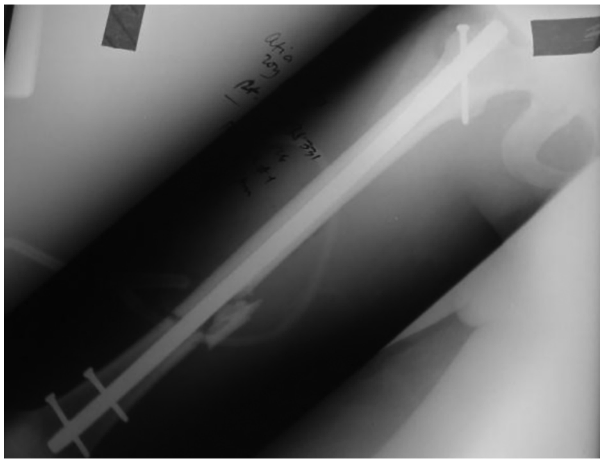
Complications	Interlocking nail (%)
Proximal screw breakage	2 (2.85)
Distal screw breakage	4 (5.75)

Figure 1



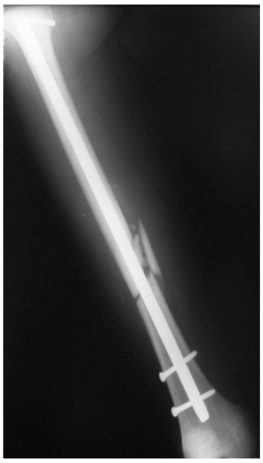
Initial radiograph demonstrating comminution and shortening of the fracture.

Figure 2



Immediate postoperative radiograph showing static interlocking fixation.

Figure 3



Radiographic evaluation during follow-up 4 months postoperatively.

Discussion

Comminuted fractures of the femur are particularly difficult to treat. Usually a result of high-energy trauma, this complex fracture is frequently accompanied by severe injuries to other organs and systems. In our study the mode of injury was RTA in 88%, fall from a height in 9%, and pedestrian in 3%. Associated injuries occurred in 35 (50%) patients. It is a matter of social concern that none of the drivers or passengers were wearing seatbelts.

Conservative treatment of comminuted femoral fractures yields unacceptable results and a high complication rate in the form of malunion and nonunion [13]. There are many benefits of early fracture stabilization: the procedure facilitates patient mobility, improves pulmonary function, and decreases pain, and thus the need for NSAIDs and narcotics. Early fracture fixation also decreases inflammatory mediator response and thus decreases thromboembolic phenomena. Overall, early stabilization of femoral fractures has been shown to decrease morbidity and mortality.

Early attempts at internal fixation of the femoral fracture with plates and screws were fraught with serious complications, especially infection and implant failure [14]. The use of a plate to achieve osteosynthesis of comminuted fractures of the femoral shaft necessitates a wide operative exposure and extensive stripping of the soft tissue, resulting in increased blood loss and operative time [15,16]. The risk of infection is increased. Failure of the plate is common and the need for primary bone graft adds additional morbidity to the procedure. Stress shielding by the plate has been blamed for residual weakness at the site of the healed fracture, with the resultant relatively high rate of refractures [17,18].

Because of these high rates of complications associated with this type of fixation, most orthopedics advocated intramedullary nailing of comminuted fractures. Open intramedullary nailing with supplemental fixation does not always produce stable osteosynthesis [11,19,20] and involves an increased risk of infection.

Conventional closed nailing eliminates unsightly scarring of the thigh, minimizes disruption of the soft tissues at the site of the fracture, reduces the risk of infection, and restores anatomical alignment [21–23]. Intramedullary interlocking nailing has become the treatment of choice for fractures of the femoral shaft fracture. Interlocking nails are weight-sharing implants that allow immediate weight bearing after static locking even in unstable fractures. They have the advantage of providing greater fatigue strength, better stability in all planes especially if locking screws are used, and providing reamed bone at the fracture site. The basic concept of interlocking nailing is to combine the advantages of closed intramedullary nailing with the added fixation of transfixing screws; this prevents axial sliding and rotation. Interlocking nailing has biological and biomechanical advantages in comparison with plate osteosynthesis [4,6,9,24].

Closed interlocking nailing requires appropriate preoperative management, preventive antibiotics, together with excellent operative techniques and skills, and is not without complications. Errors in the positioning of the patient, incorrect portals of entry, and inadequate reduction can lead to angulatory deformities, inequalities in limb lengths, and implant failure. In our study all patients were positioned laterally on the operative table during surgery. This position facilitated assessment of rotational alignment and makes insertion of the distal locking screws easier and more accurate intraoperatively [25]. Sufficient cortical contact between the proximal and distal fragments was needed so that axial and rotational loading could be withstood without loss of length or rotational malalignment of the fracture. With the advent of static interlocking nailing, more complex fractures of the femoral shaft could be treated with intramedullary techniques [26–28]. It has been shown that static locking of comminuted fractures without dynamization does not result in an increased rate of nonunion [1,29]. Many of the malunions reported in the literature were due to dynamic locking of unstable fractures [30]. Therefore, in our study of comminuted fractures, all nails were statically locked. We agree with Winquist and other authors that static interlocking fixation is necessary for all femoral fractures that have type 3 or type 4 comminution [7,24,26,27,31,32].

Brumback and colleagues [3,4] concluded that immediate weight bearing after stabilization of a comminuted shaft of the femur with an astatically locked intramedullary nail is safe when contrast has high fatigue strength (two distal locking bolts). Early mobilization reduces postoperative complications, maintains joint motion, and decreases the duration of hospitalization.

The mean union time for these femoral shaft fractures in our study was 8 months, which is comparable to the result of other studies [4,12,24].

The overall results obtained during evaluation at 12 months postoperatively according to Thoresen's criteria [1] were comparable to those of Razak *et al.* [33], in whose study four (8.50%) patients showed good results, three (6.38%) showed fair results, and one (2.12%) showed poor result. The results were designated as excellent, good, fair, or poor according to the alignment of the fracture, the range of motion of the ipsilateral knee, the degree of pain and swelling, and implant breakage. An excellent result meant that the patient had full, pain-free function of the extremity. In two patients who would have had a good result, simultaneous malalignment caused it to be downgraded to fair. In three operated femurs good results were downgraded to fair because there was significant pain and edema.

On the basis of our results, we recommend static locking of all comminuted femoral fractures. We believe that static interlocking nailing is the treatment of choice.

Noncompliance was a common problem. Patients started against medical advice to bear weight on the operated limb prematurely as a result of which we had proximal screw breakage in two patients and distal screw breakage in four patients.

Shortening and malrotation, which plagued earlier methods of treatment, are well controlled with available interlocking fixation [5]. However, fractures of the femoral shaft that are not treated by interlocking both the proximal and the distal fragment may be susceptible to postoperative loss of fixation. In our study three patients who had a comminuted fracture of the distal third of the femur developed an angular malunion, meaning that there was more than 5° of varus or valgus angulation at the site of the fracture. These fractures were treated with an interlocking nail, but the distal location permitted placement of only one locking screw. Loss of reduction occurred in all three patients. These same three patients had a limb length discrepancy of less than two centimeters, which was not associated with any functional impairment. No reconstructive operation was performed in any of these patients.

We had a low incidence of major complications related directly to the procedure. Only one (1.4%) operated femur had deep infection, but we had viewed eight (13.33%) patients with pulmonary embolism, which was the major cause of morbidity associated with bed recumbence in our study.

Advantages of interlocking nailing are as follows: it is pain free; early mobilization is possible even in the case of a highly comminuted fracture; and supplemental external support in the form of traction or cast bracing is rarely necessary.

Conclusion

Fracture of the femoral shaft is very common in the most productive years of life, being seen in 92% of individuals younger than 45 years of age, with 88% resulting from RTA. Most of the patients resume their work within 5–6 months postoperatively. This study is comparable to other international studies published in various journals, which have identified minimal complications but highest (13.33%) percentage of pulmonary embolism in a higher number of severely comminuted fractures. The present protocol of treatment has given the most satisfying results. It can be concluded that locked intramedullary nailing has become the gold standard, producing excellent results with acceptable rate of complications. We recommend static interlocking nailing for the treatment of all acute closed fractures of the femoral shaft because of the predictability of static interlocking fixation in terms of maintenance of length and alignment of the site of the fracture until union and because of the minimum risk of late refractures. Intraoperative assessment of the stability of fixation of a fracture is of paramount importance.

Finally, it is a matter of social concern that 88% of the patients in this study were victims of RTAs and that none of the drivers or passengers were wearing seatbelts.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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