Mini-Open Intramedullary Nailing of Acute Femoral Shaft Fracture: Reduction Through a Small Incision Without a Fracture Table

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Background: Femoral shaft fractures are usually treated with intramedullary nailing. In this study, we report on a modified surgical technique with reduction through a small incision for this type of fracture.

Methods: From 1994 to 1997, this technique was used on 74 patients with 82 femoral shaft fractures. Seventy patients (76 fractures) with at least 3 years of postoperative follow-up were included for clinical evaluation. The surgical technique involves a mini-wound at the fracture site, and fracture reduction is performed with 1 finger or a bone hook without the use of a fracture table.

Results: Seventy-four fractures (97%) healed in the first 6 months. In 2 patients, there was little evidence of fracture union at 6 months. One of these 2 patients was treated with an open bone graft, and the other was treated with a closed exchanging nail. Finally these 2 patients healed. The mean operation time for this procedure was 75 minutes.

Conclusion: The advantages of this procedure include that no fracture table is needed, there is a shorter operation time, there is a small amount of blood loss, and it is especially suitable for multiple trauma patients.

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Key words: **femur, fracture, mini-open, nail.**

Closed intramedullary nailing, first reported by Kuntscher in 1940,[1] is now the treatment of choice for most femoral shaft fractures. Numerous studies have demonstrated predictable and rapid fracture union, with a low complication rate.[2-12] These superior results are primarily attributed to achieving a form of biological fixation of the femur by preserving the surrounding soft tissue and fracture hematoma that are vitally important for fracture healing.[13,14]

Closed femoral nailing usually requires a fracture table and continuous traction for fracture reduction. This standard technique may result in several complications. Compartment syndrome in the well leg[15] and peroneal nerve palsy[9,16] are associated with use of a fracture table. Additionally, in polytrauma patients, avoiding the fracture table can decrease the need for patient transfer and manipulation intraoperatively. This can lead to a decreased total operative time and may be safer for patients.[17,18]

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Alternatively, closed reduction of the fractured femur can be performed with the aid of an external distracter or by manual traction,[17,19-21] with the patient on a radiolucent table. These methods are technically demanding and have a long learning curve. Inexperienced surgeons may prolong the procedure and endanger patients.

Although a traditional, open intramedullary procedure has the advantages of being easily learned, producing good reduction, and having short operative times,[22,23] it has complications such a high infection rate and a high rate of union delay, compared with the closed nailing method, and it can cause cosmetic problems.[8,13,14]

We developed a mini-open intramedullary nailing technique to obtain easy and quick internal fixation of acute femoral shaft fractures. It can be applied with regular facilities and with no specialized equipment. Our hypothesis was that if soft tissue dissection at the fracture is minimal, then it does not affect the clinical result. We began to perform this technique in 1994 on patients with femoral shaft fractures combined with hip and/or spine fractures, for whom the fracture table was unsuitable.

METHODS

We performed 82 mini-open intramedullary nailing procedures on 74 adults with acute femoral shaft fractures from 1994 to 1997. Patients with more than 2 years of follow-up were included in this study.

The initial selection criteria for our study included patients with multiple fractures involving an acute diaphyseal fracture of the femur, for whom the use a fracture table was unsuitable, and patients who had multiple system injuries that precluded a long anesthesia time. As our experience grew and the preliminary results were encouraging, we began to apply this method to most of our patients with acute femoral shaft fractures. Exclusion criteria included pathological fractures, non-acute fractures, significant open fractures (Gustilo types 2 and 3), and fracture comminutions that were considered very unstable (Winquist grade IV). All fractures in our study group were stabilized within 12 hours whenever medically feasible. For surgery that was delayed beyond this period of time, preoperative skeletal traction was done.

Medical records were reviewed to obtain the injury mechanism, associated injuries, other procedures performed during the same anesthesia, the operative time, estimated volume of blood loss, and functional results. Functional outcomes were measured according to the classification proposed by Klemm and Borrner regarding the motion of the hip and knee, the appearance of muscle atrophy, and the fracture alignment.[24] The preoperative radiographs were evaluated to determine the fracture location, patterns, and extent of comminution. The postoperative radiographs were reviewed to measure the quality of reduction and the process of fracture healing. A malunion was defined as an angular deformity of more than 5° or a leg length inequality of more than 2 cm.

Surgical techniques

Step 1. Nail entry site approach

Under general or spinal anesthesia, place the patient into the lateral decubitus position on the operating table (Fig. 1). A 8-cm skin incision is made from the tip of the greater trochanter proximally in line with the femoral shaft. Incise the fascia of the gluteus maximus in line with its fibers. Identify the subfascial plane of the gluteus maximus. Palpate the piriformis fossa. Pass a guide rod into the proximal canal until its tip is felt at the fracture site. Enlarge

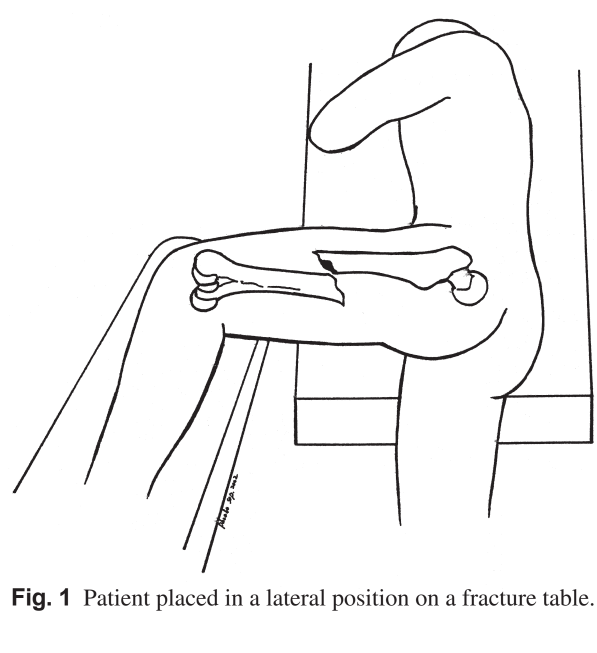

Fig. 1 Patient placed in a lateral position on a fracture table.

the proximal canal using a 9-mm reamer to allow easy passage of the guide rod.

Step 2. Fracture site approach

Make a lateral, longitudinal skin incision approximately 2.5 cm long to allow the insertion of 1 or 2 fingers. The optimal location of the incision should be determined by carefully evaluating the preoperative radiographs or by bending the fractured femur. After the incision is deepened into the fascia, the distal end of the proximal fragment is easily palpated through the defect (Fig. 2). By these means, the fracture site is approached without extensive soft tissue dissection.

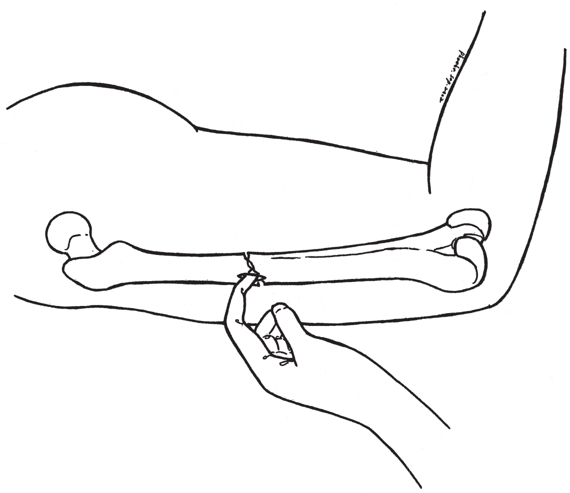

Fig. 2 The 2.5-cm incision, and manipulation with 1 finger.

Step 3. Fracture reduction

Insert the guide rod until the tip is 1 cm proximal to the distal end of the proximal canal. Reduce the fracture by manipulation with one finger of the hand, and pass the guide rod into the main distal fragment with the other (Fig. 3). This is usually easy in most oblique fractures and can be done within several minutes. In the case of a transverse fracture in which the bone overrides, use a bone hook to aid reduction. An accurate reduction is also not needed at this time.

Next ream the entire femur over the guide rod in 1 mm increments until the desired diameter and stable reductions are achieved. While remaining, it is of significant importance to keep manual traction of

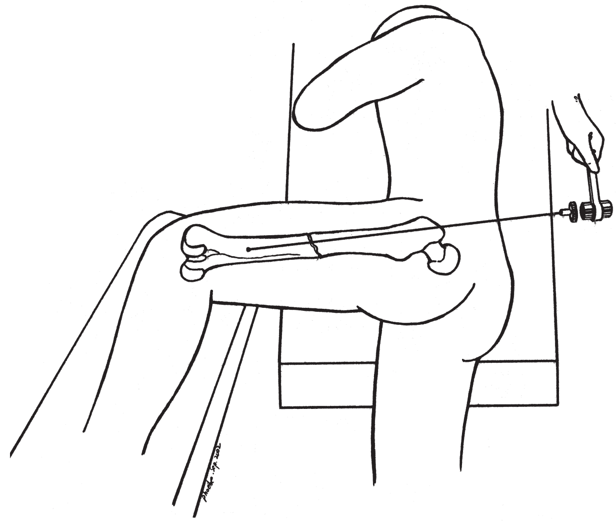

Fig. 3 Fracture reduction and passage of a guide pin through the fracture line.

the distal femur to allow better alignment. This maneuver also helps avoid further comminution by larger reamers. Palpate the fracture site as the femur is reamed to evaluate the reduction. Preservation of reaming material around the fracture site is also achieved with this technique.

Step 4. Nail insertion

Determine the length of the nail either preoperatively by measuring the opposite femur or by intraoperative measurement of the guide rod. Drive the selected nail into the canal manually with simultaneous traction of the distal femur. Insert the proximal screw, check the stability of the fixation by palpating the fracture site with both internal and external rotation of the limb. For a fracture above the isthmus, stable fixation is usually obtained at this time, and distal locking is often not mandatory.

Step 5. Distal locking

Distal locking must be done if stability is not satisfactory. When a C-arm fluoroscope is available, a good image of the distal femur should be obtained by flexing the hip and bringing the leg off the table in a lateral position. Distal locking is completed with the guide of the image identifier. In case a fluoroscope is not available, distal locking is done by the open method. Estimate the location of one of the distal screws with a nail of identical length. Use a large drill bit to create a hole in the lateral cortex in the same direction on the sagittal plane as that of the proximal screw. Enlarge the hole until the screw hole on the nail is visualized. Then drill the far cortex through the screw hole with a regularsize drill bit. When one of the distal locking screws is secured, it is easy to insert the other locking screw in a similar manner.

RESULTS

Two patients died of multiple systems injuries, and 2 other patients were lost to follow-up, leaving 76 fractures in 70 patients included in this study. There were 52 men and 18 women. The average age was 40.1 (range, 17-69) years. The majority of fractures were caused by motorcycle accidents (33/70) or motor vehicle accidents (22/70), automobiles striking pedestrians (7/70), and falls from a height (6/70) (Table 1). Fifty-three patients had associated injuries, requiring 60 additional surgeries during the same anesthesia (Table 2).

Two different surgeons performed the 76 operations; an attending doctor performed 48 procedures and a resident under the assistance of the attending doctors performed 28 procedures. Most surgical procedures (60/76) were begun within 12 hours after admission to the emergency department. Three patients underwent surgery 5 days after injury, and 1 patient underwent surgery after a delay of 8 days (Table 3). Surgeries were done via general anesthesia in 67 patients.

The mean operation time was 75 (range, 45-115) minutes (Table 4). The longer operation time was mainly due to the need for distal locking, especially when the closed technique was used. In 66 fractures that were treated with a static locking nail, the mean operation time was 70 minutes in 48 cases with an open, distal locking method versus 105 minutes in 18 cases with a closed, distal locking method. There were 10 fractures treated without distal locking, and the mean operation time in this subgroup of patients was 50 minutes (Table 5). Reduction and passage of the guide rod usually did not take more than 15 minutes. The mean estimated blood loss was 250 (range, 100-400) ml. No patient required a blood transfusion.

There were no major intraoperative problems except in 2 patients, in whom further comminution of the fracture occurred during surgery due to inadvertent forceful reaming. Nonetheless, the good results were not affected by the complications. No patient in this study required a conversion to a formal open reduction.

Fracture healing was uneventful in the majority of cases in the first 6 months; 74 fractures (97%)

Table 1. Mechanisms of Injury

Mechanism of injury	Number of patients
Motorcycle accident	33
Motor vehicle accident	22
Pedestrian struck by a vehicle	7
Fall from a height	6
Other	2

Table 2. Associated Injuries

Associated injury	No. of associated injuries
Head injury	8
Chest injury	6
Abdominal injury	18
Pelvic fracture	8
Spinal fracture	7
Tibial fracture	9
Radio-ulnar fracture	3
Humeral fracture	1

Table 3. Timing of Surgical Stabilization of Fracture

Time after injury	No. of fractures	Percent of all fractures (%)
< 12 h	60	78.9
12-24 h	12	15.8
Within 5 days	3	3.9
Within 8 days	1	1.4

Table 4. Operation Time of the Procedure

Operative time	No. of fractures	Percent of all fractures (%)
< 60 min	12	15.8
60-90 min	50	65.8
> 90 min	14	18.4

Table 5. Mean Operation Times of the Procedure

Type of distal locking method	Mean operation time (minutes)
Non-static (10/76)	50
Static (open) (48/76)	70
Static (closed) (18/76)	105

healed in the first 6 month (Fig. 4). In 2 patients, there was little evidence of fracture union at 6 months. One of these 2 patients was treated with open bone grafting, and the other was treated with closed exchange with a larger nail; these 2 fractures healed last in this study (Table 6). Of the 74 fractures that united, 3 had developed malunion by the final follow-up. Of these, a rotational malalignment of 15° occurred in 1 patient, and limb shortening of more than 2 cm occurred in 2 patients.

There were 2 superficial infections reported; both were at the incision for the entry of the nail. They were cured with debridement and antibiotics. No deep tissue infection occurred that required nail removal (Table 7).

The functional results were considered excellent in 48 limbs (63%) and good in 9 limbs (12%). The relatively high rate of poor function was attributed to a particular group of patients with significant associated injuries.

The mean hospital stay of our patients was 21 days. Most patients without a life-threatening injury were discharged after 7 to 10 days.

Table 6. Fracture Union

Healing status	No. of fractures	Percent of all fractures (%)
Union after initial nailing	74	97.3
Non-union	2	2.7
(Union after exchanging nail)	1	1.4
(Union after open bone graft)	1	1.4

Table 7. Complications of the Operation

Complication	No. of fractures	Percent of all fractures (%)
Non-union	2	2.7
Malunion	3	4.2
(malrotation)	1	1.4
(limb shortening)	2	2.7
Superficial infection	2	2.7

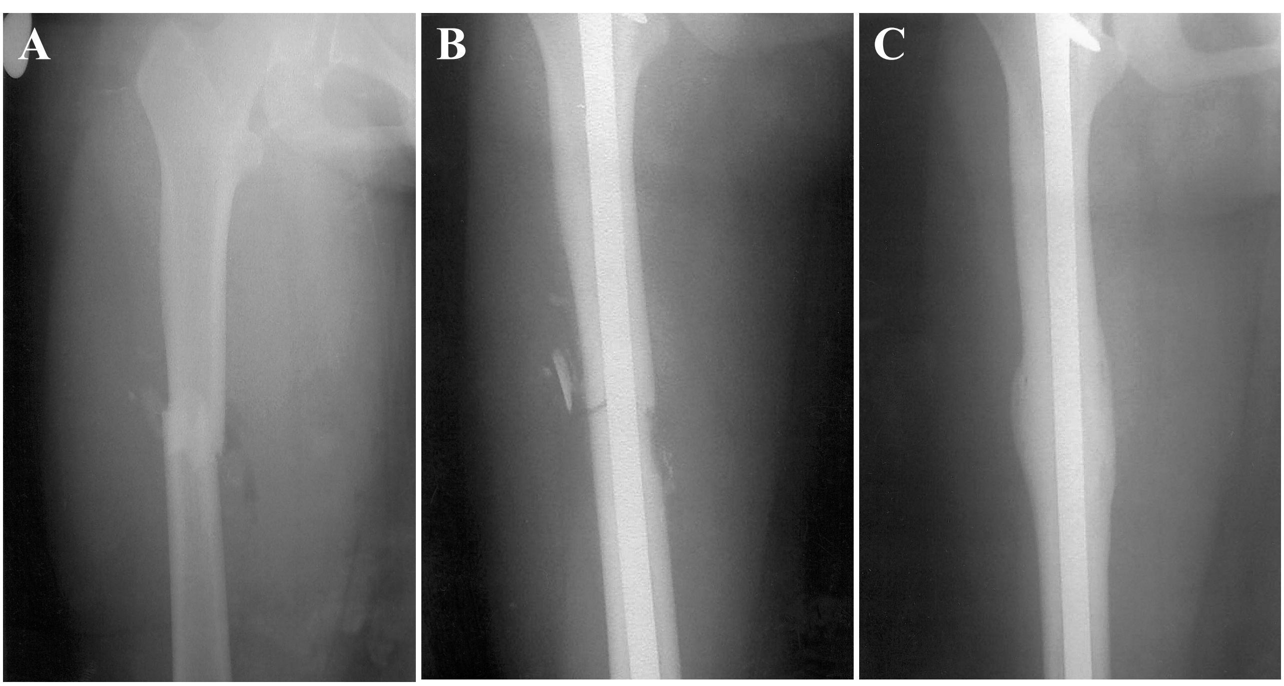

Fig. 4 (A) A 22-year-old female, initial X-ray with fractured femur. (B) The same patient, immediately post-op showing intramedullary nail and fracture reduction. (C) The same patient, 6 months later showing callus formation and complete healing.

DISCUSSION

Closed nailing allows the original hematoma to remain intact. An important point to emphasize is that closed reaming of the intramedullary canal deposits bone graft material at the fracture site.[3,14] On the contrary, open reduction and internal fixation of the fractured femur require stripping of the periosteum and subsequent reduction of the blood supply at the fracture site. This often results in extensive soft tissue damage and increased blood loss, and raises concerns of fracture nonunion and infection. Therefore, the open technique is not recommended as a routine procedure in most cases. Nonetheless, because it requires no special equipment and achieves quick stabilization, some authors advocate open nailing for polytrauma patients.[8,22,23]

The primary advantage of the closed fixation method compared to open fixation is that the bony structure can be restored with an intact soft tissue envelope. Many published studies have demonstrated superior results of closed femoral nailing, such as reliable fracture healing and a low infection rate. To obtain a closed reduction, fracture tables are currently used, although they may cause complications, and the need to transfer patients usually seriously limits the care of patients with polytrauma. Recently, techniques of closed femoral nailing without the use of a fracture table have been developed. McFerran and Johnson described the use of a femoral distracter[17] and Sirkin et al. reported a method of manual traction with the patient on a radiolucent table.[21] Although they were effective in achieving a closed reduction, the techniques seemed to be cumbersome and are unfamiliar to most orthopedic surgeons. Faced with polytrauma patients when rapid fixation is essential, these techniques may prolong the procedure and put the patient at additional risk.

Several studies in the 1980s demonstrated that a multiple-injury patient's chance of survival was increased by immediate fixation of long bone fractures.[25] Realizing the benefits, limitations, and potential complications of various methods of femoral nailing, we prefer to use the method described herein, especially for critically traumatized patients with multiple injuries. Our most important finding is that fracture healing was not compromised by the mini-open technique. In a recent and the largest study of closed, reamed femoral nailing, Wolinsky et al. reported a union rate of 93.6% after initial nailing and an overall union rate of 98.9% after an additional procedure.[12] We demonstrated a comparable union rate (97.3%) to that of closed methods. Furthermore, there were only 2 superficial infections in our study, and the small amount of blood loss associated with this approach was well tolerated. The disadvantages of open reduction are minimized by use of our new technique. The use of only 1 or 2 fingers to reduce the fracture through a small incision is important. In our experience, because an accurate reduction is not required for passage of the guide rod into the distal canal, an incision that is as small as 2.5 cm often suffices for this purpose (Fig. 5). A satisfactory reduction is usually achieved later with a larger reamer. In this way, we preserve the surrounding soft tissues, and the reamed fragments of bone collected in the flutes of the reamers also remain around the fracture site as bone graft material.

Early operative fixation in multiple trauma patients is potentially life-saving and decreases

Fig. 5 A 27-year-old male, 1 year after the operation. The length of the minimal open wound is about 2.5 cm.

pulmonary complications, mortality, multiple organ failure, and the length of stay in the intensive care unit.[26,27] More importantly with this approach, acute nailing also helps avoid soft tissue stiffness that makes reduction by fingers difficult. Most of our patients underwent surgery within 12 hours of admission. The other patients were all put in skeletal traction while awaiting fracture fixation. Although we successfully treated 1 patient 8 days after injury without the need of an extended approach, we do not recommend the use of our method in fractures with a prolonged period of delay before fixation.

One advantage of the technique is that the time needed to complete the entire procedure is short, a benefit that is crucial for emergency surgery. In experienced hands, our technique can be performed within 1 hour. It is particularly expedient if 2 trauma surgeons are available: one explores the fracture site and the other simultaneously approaches the nail entry site. Our open method of distal locking also facilitates the procedure, although there is some concern of the stability of the distal screw and the nail, because a lateral cortex might be sacrificed. Hajek et al. discussed the use of 1 or 2 distal screws in the treatment of femoral shaft fractures in a biomechanical and clinical study. The authors concluded that 1 distal screw provided adequate distal fixation.[28] We found no fracture of distal screws or fracture of the nail through the screw holes in our study. In an emergency procedure, we believe that open distal locking is particularly useful and can be performed within without increased morbidity.

The other advantage of the mini-open intramedullary nailing technique is that it significantly reduces the need for a C-arm fluoroscope. Specifically, if the open distal locking method is used, an image intensifier is not necessary. On the contrary, almost all current instrumentation systems for closed femoral nailing necessitate the use of intraoperative radiography. Although the precise risk is still unknown, the increased use of fluoroscopy has raised concerns about the dosage of applied radiation and its potential harmful effects, both to surgeons and patients.[29-31]

One important limitation of our technique is the extent of comminution. In severely comminuted fractures (Winquist type IV), there is no abutment of cortices at the fracture level, and the rotational alignment and the length stability may be hard to control. Under such conditions, the use of our method is not recommended.

Closed intramedullary nailing will continue to be the gold standard treatment for acute femoral shaft fractures. However, with careful patient selection and a proper surgical technique, our mini-open intramedullary nailing can be as safe and effective as the closed method. The union rate is high, and the complication rate is low. The procedure is quick with no need to transfer the patient, and it requires no specialized equipment. It is an ideal choice of surgery for patients with multiple injuries requiring rapid surgery and for whom transfer to a fracture table is unsuitable.

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治療急性股骨骨幹骨折的小傷口骨髓內骨釘術：不需使用骨折桌, 經由一個小切開傷口達成骨折復位

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背 景： 髓內骨釘通常被運用在股骨骨折的固定。在這個研究中，我們提出一種改良式的手術技術來治療股骨骨折。

方 法： 從1994至1997年，此手術技術被運用在74個病人 (82隻股骨骨折)，共70個病人 (76隻股骨骨折) 接受至少3年追蹤評估。手術方法包括在骨折處開一個小傷口，使用一根手指或骨鉤進行復位，而不須使用骨折桌。

結 果： 74個骨折 (97%) 在最初6個月癒合，2個病人在最初6個月不癒合。其中一個病人接受骨移植手術，另外一個病人接受閉合式骨髓內釘更換手術。在做此研究時，這二位病人的股骨骨折已癒合。此改良技術所花費平均手術時間爲75分鐘。

結 論： 這項技術的好處是不需使用骨折桌，手術時間短，手術失血少，特別適合運用在有多重外傷的病患上。

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關鍵字：股骨，骨折，小傷口，內骨釘。

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