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ORIGINAL STUDY

Retrograde dynamic locked intramedullary nailing for distal femoral aseptic nonunion associated with broken antegrade locked nail

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Techniques for treating distal femoral aseptic nonunions associated with antegrade locked nail breakage are controversial. Each technique has unique advantages and disadvantages. Retrograde dynamic locked nailing was used in such treatment.

Twelve patients with the described disorders were treated with retrograde dynamic traditional femoral locked nails. The proximal segment of the broken nail was removed from the hip area with the patient in the lateral decubitus position. Consequently, the patient was changed to the supine position. The distal segment of the broken nail was removed from the intercondylar inlet and a dynamic locked nail was inserted in a retrograde fashion. Two staples were used for reinforcing rotational stability whenever necessary. Early ambulation with protected weight bearing was encouraged.

All 12 patients with 12 nonunions were followed for an average of 2.9 years (range, 1.1-4.7 years). All nonunions healed with a union rate of 100%, and the average time to union was 4.2 months (range, 3.0-5.5 months). There were no complications of nonunions, malunions or deep infection. Satisfactory knee function among 12 patients improved from 42% pre-operatively to 100% at the latest follow-up (p = 0.002). All 12 patients could walk without aids.

The described technique may be an excellent alternative for treating a distal femoral aseptic nonunion associated with antegrade locked nail breakage. The technique is not difficult and the union and satisfactory rates are high.

Keywords : antegrade locked nail ; aseptic nonunion ; distal femur ; nail breakage ; retrograde locked nail.

INTRODUCTION

The femoral shaft may be defined as the femur between the lower border of the lesser trochanter and the upper border of the femoral condyle *(34)*. Although antegrade closed reamed locked intramedullary nailing is considered the treatment of choice for most femoral shaft fractures, its use in treating fractures at the distal femoral shaft has some limitations *(13)*. The two distal locked screws cannot steadily stabilize the distal femoral fragment with a short stock *(34,35)*. The upper distal locked screw hole nearing the fracture site has a potential risk of nail breakage *(1,2,36)*. Consequently, plate or retrograde locked nail system is advocated to compensate for this defect *(4)*.

For precisely defining an antegrade locked nail in stabilizing distal femoral shaft fractures, the distal femoral shaft may be divided into infra-isthmal and supracondylar segments *(22,34,35)*. Clinically, the total infra-isthmal and upper part of supracondylar

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segments can be stabilized with an antegrade locked nail *(34,35)*. Because both fragments have gradually enlarged medullary cavity, thin cortex, and curved contour, stable stabilization with all plate and nail systems is sometimes difficult *(4,22,27,35)*. Although implants are continuously improving, an optimal device is still controversial. Each device has unique advantages and disadvantages. None can be considered absolutely superior to others.

The incidence of aseptic nonunions of the distal femoral shaft after antegrade locked nailing is varied *(2,3,12,13,26,29,34)*. As high as an 18% nonunion rate has been reported *(34)*. Treatment of this disorder is controversial. Once an aseptic nonunion is associated with nail breakage, the treatment becomes even more complicated and an optimal technique for treatment has not be convincing. Currently, retrograde dynamic locked intramedullary nails gradually achieve supports to treat distal femoral aseptic nonunions after failed various unlocked or locked plate treatment *(29,32)*. Furthermore, it is also useful in treating aseptic nonunions after failed antegrade locked nailing without nail breakage *(30)*. Whether a retrograde locked nail can still be useful in treating nonunions with nail breakage? To the best of the author's knowledge, few articles had addressed this issue. The purpose of this retrospective study was to evaluate retrograde dynamic locked nailing in the treatment of distal femur aseptic nonunions with antegrade locked nail breakage. A more reasonable treatment technique might then be recommended.

MATERIALS AND METHODS

From July 2005 to December 2013, 12 consecutive adult patients (> 18 years) with 12 distal femoral aseptic nonunions associated with antegrade locked nail breakage were treated with retrograde dynamic locked intramedullary nailing at the author's institution (Fig.1a). The author treated and followed all patients. The patients aged from 24 to 47 years (average, 34 years), and the male to female ratio was 3:1 (Table 1). Inclusion criteria for this study were patients with distal femoral aseptic nonunions associated with antegrade locked nail breakage. Patients with nonunions not treated by

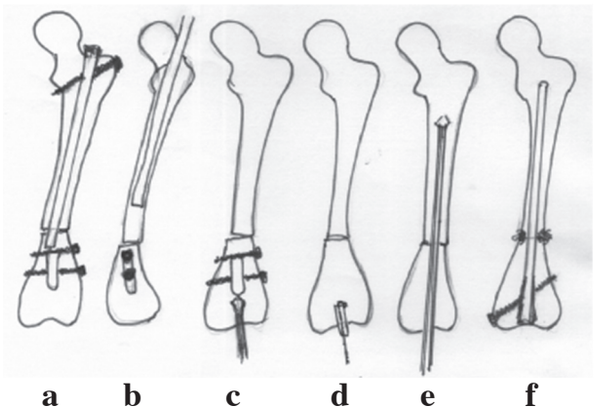

Fig.1. — The sequence of revision technique: (a) A distal femoral aseptic nonunion with antegrade locked nail breakage requires treatment. (b) The proximal segment of the broken nail is removed from the hip area with the patient in the lateral decubitus position. (c) The intercondylar inlet is made and reamed with the patient in the supine position. (d) The distal segment of the broken nail is hooked out from the intercondylar inlet. (e) The marrow cavity is reamed as widely as possible. (f) A retrograde dynamic locked nail is inserted and bone graft is packed

retrograde dynamic locked intramedullary nailing were excluded from the study, as were patients younger than 50 years of age who had leg length discrepancies greater than 2 cm. The latter group was treated with concomitant lengthening techniques *(33)*. Patients with suspicious deep infections were advised to be treated with external fixation and were excluded from the study, while those who had previous deep infections that had subsided were included in the study.

At the outpatient department (OPD), patient's treatment course was inquired carefully. All fractures were initially caused by high-energy injuries, such as automobile or motorcycle accidents, or falls from heights. There were no open fractures *(6)*. All 12 fractures were initially treated at other hospitals. Two fractures had resulted in deep infections (cases 6 and 9, Table 1). After repeated surgical treatment and antibiotic use, no infection recurred over 1.8 and 1.2 years, respectively. The period from the initial injury to the present revision surgery averaged 1.7 years (range, 0.7- 2.5 years), and patients required from 1 to 4 surgeries (average, 2.0 surgeries). The knee range of motion (ROM) averaged 107°of

Table 1.— Data of patients with distal femoral aseptic nonunions and broken antegrade locked nails treated by the described technique (n=12)

Case no.	Age/Gender	Injury periods (yrs)	Operative numbers	Pre-op knee ROM (deg)	Staple augment	Union period (mos)	latest knee ROM (deg)	Functional grade of knee	Follow -up (yrs)
1	36/M	1.8	1	0-60	N	4.5	0-120	G	4.7
2	47/M	2.4	2	5-100	Y	5.0	5-130	G	4.2
3	32/M	1.5	4	0-120	N	5.0	0-140	G	3.8
4	27/F	1.2	2	5-120	N	4.0	0-130	G	3.5
5	34/M	2.0	1	0-140	N	3.5	0-140	G	3.4
6*	44/F	2.5	4	0-100	N	5.5	0-130	G	3.0
7	30/M	1.7	2	5-70	Y	4.0	0-120	G	2.8
8	24/M	1.2	1	0-100	N	3.5	0-120	G	2.6
9*	33/M	1.9	4	0-100	Y	4.0	0-120	G	2.2
10	41/F	1.8	1	5-120	N	4.5	5-140	G	1.8
11	32/M	1.6	1	0-140	N	3.5	0-140	G	1.7
12	24/M	0.7	1	0-110	N	3.0	0-130	G	1.1

F, female; G, good; M, male; N, no; ROM, range of motion; Y, yes; *, infection history

maximal flexion (range, 60°-140°), and 2 patients had less than 90°of knee flexion (cases 1 and 7). All patients were dependent on walking aids.

At the OPD, the fracture and wound healing processes of all patients were also carefully investigated. The knee ROM of each patient was measured with goniometry. Plain radiographs of the femur and knee, and full length standing scanogram were routinely checked. The treatment plans were thoroughly explained to the patient and family. The ideal approach was determined.

At admission, complete blood cell (CBC) count, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) levels were routinely checked. Patients who had previous deep infection (cases 6 and 9) but subsided at the present time were treated, and vancomycin and ceftazidime were locally used intra-operatively.

Surgical technique

Patients received generalized anesthesia with endotracheal intubation. First, the patient was placed in the lateral decubitus position at the operating table. The upper segment of the broken locked nail was removed from the piriformis fossa and the wound was closed with non-absorbable sutures (Fig.1b).

Consequently, the patient was changed to the supine position and a sterilized pneumatic tourniquet was used, which could be removed whenever necessary.

For patients with knee flexion greater than 90°, a medial para-patellar approach was performed and the knee joint was opened. For those with less than 90°knee flexion (cases 1 and 7), a midline approach with inverted quadriceps flap incision was performed and the knee was bent to 90°. A 3 mm Kirschner wire (Mizuho Medical Co. Ltd., Tokyo, Japan) was inserted in the intercondylar notch 5-10 mm anterior to the insertion of the posterior cruciate ligament. An 8-14 mm reamer was used to enlarge the bony inlet in the intercondylar notch (referring to the size of the removed antegrade locked nail). The nonunion site was explored and debrided. The distal locked screws were removed. With forceful

manipulation, the femur alignment was reduced. Consequently, a flexible guide wire was inserted in a retrograde fashion from the bony inlet to the broken nail (Fig.1c). Reaming was performed again and the broken nail was hooked out or pushed out from the intercondylar inlet (Fig.1d).

The marrow cavity was then reamed as widely as possible (Fig.1e). After this, a 1-mm smaller traditional femoral locked nail (Smith & Nephew, Memphis, TN, USA; or Zimmer, Warsaw, IN, USA) was inserted in a retrograde fashion. Only the lower diagonal locked screws were inserted (Fig.1f). The rotational stability was checked manually. If rotational stability was insufficient, two staples (Richards, Memphis, TN, USA) were augmented. Cancellous bone graft procured from the ipsilateral tibial condyle and bone graft substitutes (Wiltrom Medical Inc., Hsinchu, Taiwan; 60% hydroxyapatite and 40% β-tricalcium phosphate) were packed in the nonunion site (Fig.1f). For patients with prior deep infection, 6 vials of vancomycin (500 mg/vial, Tai-Yu Co., Hsinchu, Taiwan) and ceftazidime (500 mg/vial, China Chemical & Pharmaceutical Co., Taipei, Taiwan) powders were placed in situ. Bone graft was mixed with antibiotic powder and placed in the gap. The wound was closed with non-absorbable sutures and a closed drain was inserted. For patients treated with the quadriceps flap approach, the quadriceps tendon was sutured with a V-Y mode with the knee in 80°flexion.

After surgery, progressive knee ROM exercise was encouraged, and patients were permitted to walk as early as possible using protected weight bearing. A continuous passive motion (CPM) device (OrthoLogic Canada Ltd., Toronto, Canada) was used with gradual increasing knee flexion. Patients were followed up at the OPD at 4 to 6 week intervals. Clinical and radiological fracture healing processes were then evaluated. After the fracture healed, patients were followed up each year and whenever necessary. Knee function evaluation was recorded at each follow-up.

Fracture union was defined as clinically lack of pain and tenderness at the fracture site, and the ability to walk without aids. In addition, solid callus had bridged the fragments in three of four views on plain radiographs *(8,20)*. A nonunion was defined as the fracture site had not healed after 1-year of treatment or when a second surgery was necessary to achieve a union *(24)*.

Knee function was evaluated using the modified Mize scoring system, which was selected because of its simplicity and relative practicality *(17)*. Outcome included four grades, and a satisfactory result was defined as an excellent or good grade. An excellent grade consisted of: (1) absence of pain, (2) < 10°flexion loss, (3) full extension, and (4) no varus, valgus or rotational deformity. A good grade consisted of no more than one of the following: (1) > 20°flexion loss, (2) > 10°extension loss, (3) > 5°varus or valgus deformity, (4) >10°rotational deformity, (5) minimal pain.

Fisher's exact test or paired Student's t-test was used for statistical comparison. Statistical significance was $p < 0.05$.

RESULTS

All 12 patients with 12 nonunions were followed up for at least one year (average, 2.9 years; range, 1.1-4.7 years). Three of the 12 knees required staple augmentation to protect the patients from rotational instability (cases 2, 7, and 9).

Cancellous bone grafting was performed in all 12 patients and bone graft substitute was added in 4 patients.

All 12 fractures healed with a union rate of 100% (12/12) and an average union time of 4.2 months (range, 3.0-5.5 months; Figs. 2, 3).

There were no complications of nonunions, malunions (> 5°varus, valgus or >10°rotational deformity) or deep infection. The re-operation rate was zero.

At the latest follow-up, the knee range of motion (ROM) averaged 131°of maximal flexion (range, 120°-140°, $p < 0.001$, Table 1),

Satisfactory knee function was improved from 41.7% (5/12) of patients preoperatively to 100.0% (12/12) at the latest follow-up ($p = 0.002$, Table 1). All patients could walk without aids.

Usually, the retrograde nail was suggested to be removed in patients with prior infection after two years. For patients without prior infection, implants were removed as patients' request. At the latest follow-up, 8 nails were removed.

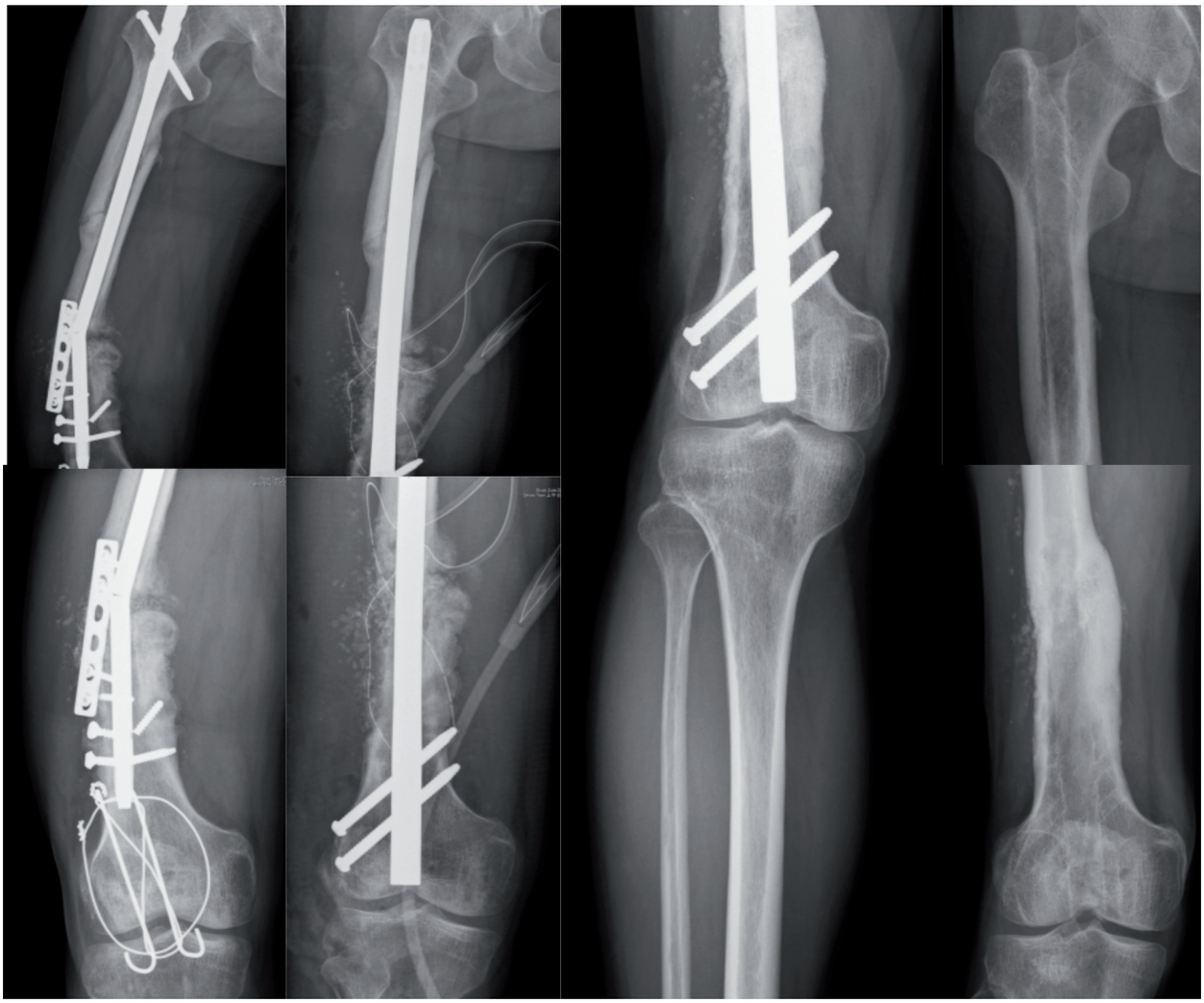

Fig. 2. — Case 1. A 36-year-old man sustained a right distal femoral aseptic nonunion with antegrade locked nail breakage for 1.8 years. The nonunion was treated with the described technique. The fracture healed within 4.5 months. At the 4.7-year follow-up, the patient had good knee function

DISCUSSION

For more effective treatment of a nonunion, a hypertrophic or atrophic type is classified **(19,28)**. The former is caused by unstable stabilization of fracture fragments and an optimal treatment is providing sufficient stability. The latter is due to loss of osteogenic power and an optimal treatment requires both providing sufficient stability and stimulating osteogenic potential. For distal femoral aseptic nonunions with antegrade locked nail breakage, both types may be possible. Therefore, both mechanical stability and biological vitality should be managed concomitantly *(19)*. In the current technique, both factors are corrected and a 100% union rate is achieved.

Techniques for providing sufficient stability in treating distal femoral nonunions associated with antegrade nail breakage are multiple. Exchange locked nailing, unlocked or locked plate augmentation with or without removal of the broken nail, and retrograde locked nailing are feasible *(9,18,23,29,34,37)*. However, each technique has unique advantages and disadvantages and an

Fig. 3.— Case 2. A 47-year-old man sustained a right distal femoral aseptic nonunion with antegrade locked nail breakage for 2.4 years. The nonunion was treated with the described technique. Two staples were augmented to reinforce rotational stability. The fracture healed within 5.0 months. At the 4.2-year follow-up, the patient had good knee function

optimal technique is not convincing. After all, sample sizes in all prior studies are small. The optimal treatment requires consideration of both clinical and theoretical advantages.

Exchange nailing with closed removal of the broken nail may achieve as high as a 100% success rate *(37)*. Although the wound is small and an infection rate is low, it cannot correct knee contracture concomitantly. Moreover, the risk of nail re-breakage still exists *(2,36)*. Augmentation with various plates and the broken nail being in situ or removed can also achieve as high as a 100% success rate *(23,34)*. However, if the broken nail is not removed concomitantly, there is no chance of removal forever. In the nonunion site, a plate cannot be applied with a minimally invasive percutaneous plate osteosynthesis (MIPPO) technique due to local scarring. A large surgical wound with soft tissue destruction may interfere with bony healing process *(19)*.

Retrograde locked nails have not been reported in treating distal femur nonunions with antegrade nail breakage. In the current study, a 100% success rate is achieved. Concomitant correction of knee contracture is feasible. The most common concern may be an optimal technique in removing the broken

nail. In the literature, techniques for removal of a broken nail are multiple *(15,25,37)*. Closed removal of both proximal and distal segments of the broken nail from the piriformis fossa has been reported *(37)*. Consequently, antegrade or retrograde insertion of a new locked nail can be performed. Or, a new locked or unlocked plate may be inserted.

Treatment of distal femoral nonunions with a locked or unlocked plate can achieve a high union rate. Biomechanically, the stability of a plate is highly superior to an antegrade locked nail in the distal femur. However, soft tissue compromise may be severe with plate insertion because the local scars must be removed whenever necessary for inserting the plate. Therefore, cancellous bone graft had better be supplemented *(19)*. Similarly, cancellous bone graft should be supplemented in the current technique. Koval et al. had reported a poor outcome using a retrograde locked nail without cancellous bone grafting in treating distal femoral nonunions after failed antegrade locked nail treatment *(10)*. The simple reaming effect in a retrograde fashion is considered small.

In the current study, the proximal nail segment is removed with the patient in the lateral decubitus position and the wound is closed immediately. The distal nail segment is removed after the patient is changed to the supine position. Therefore, no wound exists during skin preparation for the second surgery. The knee must be realigned with the patient in the supine position. Or, angular deformity easily occurs. The grossly acceptable alignment can be checked using the "cable" or "deviation angle" technique *(11,31)*. Removal of the whole prior broken locked nail with patients in one-position is technically difficult. Although the proximal nail segment may be pushed out of the piriformis fossa from the intercondylar inlet, it does not always succeed *(16)*. A different nail manufacturer or the proximal nail segment incarcerated by a broken proximal screw makes nail removal very difficult and complicated. With the patient in the lateral decubitus position, removal of the proximal nail segment is easier. Consequently, removal of the distal nail segment with conversion to a retrograde nail is performed.

In the current study, a dynamic mode of traditional femur locked nails is used and staples are supplemented whenever rotational instability is suspected. All nonunion had achieved a solid union. For a classic supracondylar nail, stress rising may introduce shaft fractures before the nonunion heals *(14)*. Therefore, the retrograde nail end must reach the lesser trochanter level, which makes insertion of the upper locked screws difficult and risky *(21)*. In the current study, all nails are in a dynamic mode and upper locked screws are not inserted. The upper fragment stability depends on the three-point fixation principle *(5)*. Two staples are prepared for necessary augmentation. A dynamic locked nail is a load-sharing device, which can not only decrease nail breakage incidence but also promote osteogenesis *(7,19)*.

The limitations of the current study include a small sample size, which may introduce possible bias for treatment evaluation. After all, such cases are rare. Although a retrograde locked nailing technique may be excellent theoretically, a relatively longer time with more case number collection is necessary. Besides, no controlled studies can be addressed for comparison among various surgical techniques. An optimal revision technique therefore cannot be definitely concluded. The surgical technique for the order of broken nail removal may be modified. The current technique avoids making a wound during skin preparation for the second surgery when the patient is changed to the supine position. Therefore, wound contamination may be avoided and infection may be minimized.

In conclusion, a retrograde dynamic traditional femoral locked nail may be an excellent alternative and an optimal choice for treating distal femoral aseptic nonunions associated with antegrade locked nail breakage. The technique is not difficult, and the union rate and satisfactory function rate are high.

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