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Original Article

Revision surgery for femoral shaft aseptic nonunion associated with broken distal locked screws☆

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femoral shaft nonunion
locked screw breakage
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A B S T R A C T

Purpose: This retrospective study was to report the experience in treating femoral shaft aseptic nonunions associated with breakage of distal locked screws.

Materials and Methods: Thirty-two femoral shaft aseptic nonunions associated with breakage of both distal locked screws in 30 consecutive adult patients with 32 nonunions were treated. Eleven nonunions were concomitantly associated with at least 1.5 cm (1.5–3.5) shortening. These 11 nonunions were treated by one-stage nail exchange and femoral lengthening, static locked nailing stabilization, and corticocancellous bone graft supplementation, whereas other 21 nonunions were treated with less than 1.5 cm shortening, simple exchange nailing only.

Results: Twenty-eight nonunions were followed-up for a median of 3.8 (1.1–6.2) years and 26 fractures healed at a median of 4 (3–9) months. Either group had one persistent nonunion ($p = 0.48$) and was successfully treated with repeated exchange nailing or open cancellous bone grafting.

Conclusions: Using exchange locked nailing or one-stage femoral lengthening to treat femoral shaft aseptic nonunion associated with broken distal locked screws can achieve a high success rate. The key of the technique to remove broken screws is withdrawing the nail a little bit to release the incarcerated broken screw end. Then, the screw end is pushed out with a used Knowles' pin or a smaller size screwdriver under the image intensifier guidance.

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1. Introduction

Despite that unlocked or locked reamed intramedullary nails have been the treatment of choice for most of femoral shaft fractures, a nonunion rate may still be as high as 10%.[1,2] A femoral shaft nonunion following locked nail stabilization may be sometimes associated with implant failure—nail or distal locked screw breakage, which consequently worsen the fracture stability.

Articles reporting treatment of a femoral shaft nonunion associated with breakage of a locked nail are not few.[3] On the other hand, to the best of the authors' knowledge, articles reporting treatment of a femoral shaft nonunion associated with breakage of distal locked screws are rare. Although an incidence of 0%–8% has been reported as an aside in the literature, all cases are imputed to using a small caliber of locked screws for a small diameter of locked nails.[4,5]

Methods used to treat such a disorder may be multiple. Theoretically, revision with a new intramedullary nail should be relatively better. However, articles reporting techniques of revision with a new intramedullary nail are few. Moreover, sample sizes of these articles are so small that the outcome of treatment is still uncertain.[5,6] Whether is revision with a new intramedullary nail a better choice? The aim of this retrospective study was to review the technique of revision with a new intramedullary nail with or without simultaneous correction of shortening. The feasibility of this technique was thoroughly investigated.

2. Materials and methods

From October 2000 to November 2006, 32 femoral shaft aseptic nonunions associated with breakage of both distal locked screws in 30 consecutive adult patients (>15 years) were treated at the authors' institution. Patients aged a median of 29 (19–56) years with a male to female ratio of four to one. Twenty-eight nonunions were unilateral and two nonunions were bilateral. All nonunions were caused by failed fracture treatment before, and all fractures were initially caused by vehicle crashes. Twenty-five fractures had been treated initially at other hospitals. The previous

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fracture site was upper 1/3, 5; middle 1/3, 9; distal 1/3, 18. Ten nonunions were treated with dynamic locked nails, whereas other 22 were treated with static locked nails. The interval from the injury to the revision surgery was 14 (6–36) months. The previous operations had been performed for one to four times. Finally, all cases suffered nonunions with breakage of both distal locked screws. All these aseptic nonunions were atrophic nonunion because the local stability was maintained well until distal locked screws broke.

At the outpatient department, the wound healing process was carefully inquired and the local area was thoroughly inspected. Leg length discrepancy was assessed by spinomalleolar distance with or without scanogram. More than 1.5 cm of shortening was indicated for one-stage femoral lengthening concomitantly. However, more than 5 cm of shortening was indicated for gradual lengthening by the Ilizarov technique and was excluded from this study. In this series, 11 of 32 nonunions were associated with 1.5–3.5 cm shortening and were treated with one-stage femoral lengthening concomitantly. The other 21 nonunions were treated with simple exchange nailing only.

At admission for revision surgery, white blood cell, erythrocyte sedimentation rate, and C-reactive protein were routinely checked. Cases with suspicion of deep infection would be treated with external fixation. In this series, data of all 32 nonunions were within normal range.

2.1. Surgical technique

Under general anesthesia, patients were placed on the fracture table in the lateral decubitus position. Skeletal traction with a 2.4-cm Kirschner wire in the femoral condyle was performed for all 32 patients. An image intensifier was prepared.

For nonunions with less than 1.5 cm of shortening, the distal locked screws were checked with the image intensifier first. The proximal part of broken locked screws was removed with a screwdriver. A second skin wound was made on the trochanteric area and the inserted locked nail was withdrawn a little bit with a target device. The distal part of the broken locked screw became vertical to the nail and was confirmed by the image intensifier. With a used Knowles' pin or a smaller-size screwdriver placed into the screw hole, the distal part of the broken screw was pushed forward. The disengaged screw end was confirmed by the image intensifier and was left alone.

The locked nail was removed with a target device. The marrow cavity was reamed as widely as possible until strong resistance was felt. Usually, only overreaming of 1–3 mm could be gained. Then, a 1 mm smaller sized locked nail (Howmedica, Kiel, Germany) or Küntscher nail (Zimmer, Warsaw, IN, USA) was inserted. Nails of a dynamic mode were preferred and a static mode was used in cases with more than 1 mm overreaming when an adequate size of the nail was unavailable.

For nonunions with more than 1.5 cm shortening, corticocancellous bone graft with the required amount was procured from the posterior iliac crest first.

The broken screws and the prior locked nail were removed as the described way. Then, the nonunion site was opened and the local area was thoroughly debrided. A spine spreader was placed between fracture fragments to assist the lengthening procedure until the desired length was reached. The femur length was maintained with the skeletal traction and the marrow cavity was reamed as widely as possible. Similarly, only overreaming of 1–3 mm could be gained. A 1 mm smaller sized static locked nail was inserted and bone graft was packed to fill the gap. The wound was closed without drain insertion.

Postoperatively, patients were permitted to ambulate with protected weight bearing as early as possible. Quadriceps as well as knee range of motion exercise was encouraged. Follow-up at the outpatient department with 4–6 week interval was arranged. Clinical and radiographic fracture healing processes were recorded. Crutches had to be used until fractures had completely healed.

Fracture union was defined as clinically, no pain, no tenderness, and patients could walk without aids; radiographically, solid cortical callus had bridged both fragments. Nonunion was defined as a fracture was still ununited after 1-year treatment or fragment stability was lost and repeated revision surgery was necessary to achieve the union.[7,8]

Lengthening or simple exchange nailing group was concomitantly compared to investigate the clinical difference. Fisher's exact test or two-tailed unpaired Student's *t*-test was used for statistical comparison. A $p < 0.05$ was considered significantly different.

3. Results

Twenty-eight nonunions in 26 patients were followed-up for a median of 3.8 (1.1–6.2) years and four patients were lost despite all efforts to contact. Ten nonunions with lengthening in 10 patients and 18 nonunions without lengthening in 16 patients had completed this study (Table 1).

Nine of 10 nonunions in the lengthening group healed (Figs. 1 and 2), whereas 17 of 18 nonunions in the nonlengthening group also healed ($p = 0.48$; Fig. 3). The union period in the former was a median of 4 (3–6) months and the latter a median of 4 (3–9) months ($p = 0.38$).

The operation time in 11 nonunions with lengthening was a median of 150 (110–200) minutes and the nonlengthening group a median of 50 (30–70) minutes ($p < 0.001$).

Blood loss in 11 nonunions with lengthening was a median of 800 mL (400–2,000) and eight patients required blood transfusion. In the non-lengthening group, all cases were treated with closed nailing technique. The blood loss during closed nailing procedures could not be estimated exactly because most of the blood stayed in the intramedullary canal and only small amount of blood was found in the proximal wound. There were no patients who required blood transfusion in the nonlengthening group.

Range of motion of the knee was always satisfactory no matter whether the femur was lengthened or not (average, 128°; range, 110°–140°). There was no deterioration after the revision surgery and all patients could bend the knee over 110°.

There were two persistent nonunions and one was in each group. The nonunion case in the lengthening group broke locked screws again at 5 months postoperation and was treated with reexchange nailing. The fracture healed uneventfully at 4 months after second revision fixation (Fig. 4). The other nonunion case in the nonlengthening group was treated with open cancellous bone graft procured from the ipsilateral tibial condyle. The fracture also healed uneventfully at 4 months after operation.

Besides, there were no wound infection and angular (>10°) or rotational (>10°) deformity. There were no cases with further shortening in the lengthening group because all these patients were treated with static locking nails.

4. Discussion

Distal locked screws are usually inserted for enforcing distal fragment stability in distal shaft fractures or maintaining shaft length in comminuted shaft fractures. Once both distal locked screws break, distal fragment will lose stability immediately in distal shaft fractures. However, in comminuted shaft fractures, locked screws break may cause shaft instability and shortening. The nonunion level in the shaft may also cause either complication.

Table 1
Clinical data for 32 femoral shaft nonunions associated with breakage of distal locked screws.

Case	Age (yr)	Sex	Interval from injury (mo)	Prior operation times	Prior nail mode	Associated shortening (cm)	Revised nail mode	Operation time (×10 min)	Blood loss (×100 mL)	Bony union (mo)	Follow-up (yr)
1	50	M	15	1	D	0	D	6	U	4	6.2
2	22	M	15	1	S	0	D	5	U	4	6.0
3	29	M	10	2	D	3	S	18	18	T	T
4	20	M	12	2	S	1	D	6	U	3	5.8
5	44	M	18	1	S	0	D	5	U	3	5.8
6	22	F	16	1	D	2.5	S	15	12	4	5.5
7	52	M	36	2	S	0	D	5	U	T	T
8	19	M	14	1	D	1.5	S	11	4	3	5.3
9	35	F	12	1	D	2	S	16	6	6	5.2
10	29	M	11	2	S	1	S	5	U	T	T
11	56	M	8	1	S	1	D	5	U	4	4.6
12	28	M	12	2	S	3.5	S	20	18	N	4.6
13	47	F	22	3	D	2	S	14	8	3	4.3
14	26	M	11	1	S	0	D	5	U	4	4.2
15	32	M	24	1	D	2	S	18	6	3	3.9
16	49	M	26	2	S	0	D	7	U	4	3.8
17	49	M	26	2	S	0	D	6	U	4	3.8
18	24	M	24	1	S	0	D	5	U	4	3.7
19	20	M	8	2	S	1	S	7	U	6	3.6
20	36	F	10	2	S	0	D	5	U	5	3.4
21	21	F	30	1	D	2.5	S	16	8	6	3.0
22	41	M	10	2	D	3	S	18	20	4	2.8
23	32	M	24	2	S	1	S	5	U	T	T
24	25	M	13	3	S	1	D	7	U	4	2.2
25	25	M	13	3	S	0	D	5	U	4	2.2
26	31	M	10	1	D	2	S	12	8	4	1.8
27	24	M	13	1	D	2	S	14	6	4	1.8
28	38	M	14	1	S	0	D	3	U	N	1.6
29	25	F	16	4	S	0	D	4	U	9	1.6
30	39	M	15	1	S	1	S	6	U	5	1.2
31	23	M	6	2	S	1	D	4	U	7	1.2
32	21	M	16	1	S	1	D	5	U	4	1.1

Cases 16, 17 and Cases 24, 25 were bilateral nonunions.
D = dynamic; F = female; M = male; N = nonunion; S = static; T = lost; U = unavailable.

Therefore, revision surgery may choose a new locked nail or a Küntscher nail as different requirement.

A static locked nail is a load-bearing device, whereas a dynamic locked nail or a Küntscher nail is a load-sharing device.[9–11] Therefore, theoretically a load-sharing nail should be preferentially used to prevent implant failure. A static locked nail should be preserved for fractures unfit for load-sharing nail stabilization, such as overreaming more than 1 mm, which may induce rotational instability or a lengthening technique to maintain the length.

In the literature, one distal locked screw insertion has been advocated to shorten the operation time and reduce radiation exposure.[12–14] However, insertion of only one distal locked screw may be insecure throughout the fracture healing process. Practically, both distal locked screws had better be inserted as possible. All 32 cases in the present series had broken both distal locked screws. The cause should be long-term full weight bearing without protection. Although the second locked screw may reduce the loads on the first locked screw, the latter may fail following failure of the former.[15,16]

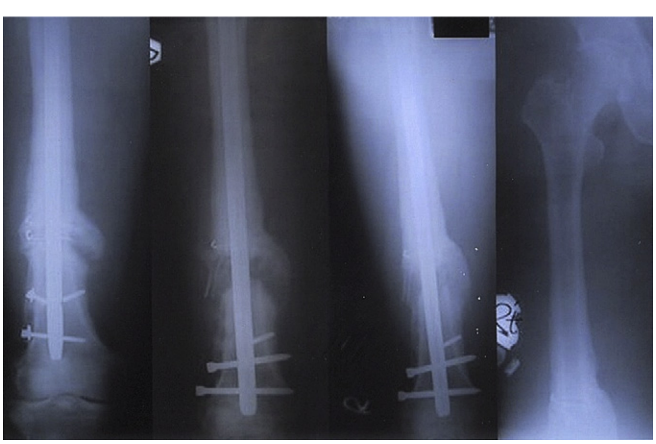

Fig. 1. Case 6—A 22-year-old woman sustained a right lower-third femoral shaft fracture, which was treated with open dynamic locked nailing and wiring. A nonunion, both distal locked screw breakage, and shortening of 2.5 cm occurred for 16 months. One-stage lengthening, static locked nailing, and bone grafting introduced a bony union at 4 months.

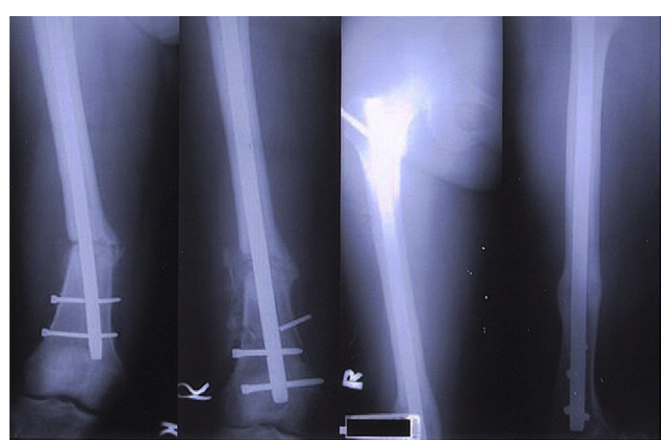

Fig. 2. Case 9—A 35-year-old woman suffered a right lower-third femoral shaft fracture, which was treated with dynamic locked nailing. A nonunion, valgus deformity, shortening of 2 cm, and both distal locked screw breakage occurred for 12 months. One-stage lengthening, static locked nailing, and bone grafting introduced a bony union at 6 months.

Fig. 3. Cases 24 and 25—A 25-year-old man sustained bilateral femoral shaft fractures, which were treated with bilateral static locked nailing. Bilateral nonunions with both distal locked screw breakage occurred at 13 months. Exchange nailing with bilateral static locked nailing was performed. Bony union occurred uneventfully at 5 and 7 months, respectively.

To easily remove the broken screw end, the locked nail should be withdrawn a little bit and the screw end becomes vertical to the nail. Or, the slant screw end will be incarcerated between the nail and the medial cortex, which will hinder the screw end being pushed forward.

Technically, the distal part of the broken screw was pushed forward to disengage from the locked nail.[5,6,17] Then, the locked nail was removed from the trochanter inlet. The screw end may fall into the marrow cavity and removal of it becomes very difficult. Generally, it would not induce any discomfort and can be left *in situ*.[13,18] If the screw end falls into the medial muscular envelop, it can be removed by medial skin incision concomitantly or just waiting until the nail is removed.[5]

In the literature, overreaming of 1–2 mm for providing internal cancellous bone graft has achieved a high union rate in the treatment of femoral shaft nonunions.[1,8] In this series, all nonunions were overreamed of 1–3 mm and a high union rate was achieved. It revealed that the amount of cancellous bone graft seemed to be not so important and fragment stability might be more critical.

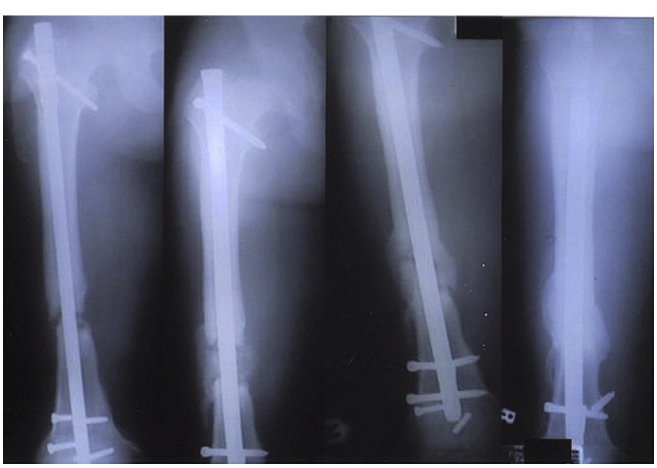

Fig. 4. Case 12—A 28-year-old man sustained a right femoral shaft fracture, which was treated with a static locked nailing. A nonunion, both distal locked screw breakage, and shortening of 3.5 cm occurred for 12 months. One-stage lengthening, static locked nailing, and bone grafting were performed. However, both distal locked screws broke again at 5 months. Exchange nailing with a dynamic locked nail introduced a bony union at 4 months.

In the literature, leg length discrepancy of more than 2 cm will induce a limp.[11] In this series, 11 nonunions were associated with more than 1.5 cm of shortening and concomitant lengthening was performed. The shortening might be caused by nonunion-associated shortening in dynamic nail fixation or initially inappropriate reduction in comminuted shaft fractures.[8] For theses cases, concomitant lengthening may be imperative to achieve a satisfactory result.

For nonunions requiring no lengthening, simple exchange nailing should be a better choice.[19–22] The advantages include a small surgical wound, minimal blood loss, shorter operation time, and a high union rate, which is superior to other known techniques. In this series, only one of 18 cases fails to unite and the success rate is 94%. In the literature, although a 53% success rate has ever been reported,[23] most of articles have reported a high success rate of 86%–100%.[21,22,24–26]

In the literature, the stress of distal locked screws of a femoral locked nail has been carefully studied biomechanically.[15,16] When the nonunion level is proximal to the isthmus (with nail-cortical contact), the screw stress will decrease as the nail-cortical contact and the length of the nail increase. Addition of a second screw distal to the first locked screw can reduce the stress of the first locked screw by up to 20%. On the contrary, when the nonunion level is distal to the isthmus (without nail-cortical contact), the screw stress will increase as the distance between the screw and the nonunion site increase because of the increased deflection of the nail.[15] This stress is generally several times higher than that in the situation with nail-cortical contact. A second locked screw addition can reduce the first locked screw stress by about 30%. Deduced from the above article, there is a conflicting concept to use a longer locked nail in distal femoral fractures.[11,16,27] However, a second locked screw should be inserted to reduce the stress of first locked screw.[15,16]

In conclusion, femoral shaft aseptic nonunions associated with breakage of distal locked screws are not unusual. It is usually caused by inadequate load protection during fracture healing process. Some nonunions may be concomitantly associated with significant bony shortening. Techniques of treatment include femoral lengthening or simple exchange nailing and both require removal of broken screws first. Generally speaking, the revision surgery can achieve a high success rate. Because breakage of distal locked screws is not unusual, the opinion of one screw insertion may need amendment to reduce a reoperation rate.

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