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Exchange nailing for aseptic nonunion of the femoral shaft

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Abstract Thirty-six nonunions of the femoral shaft were treated by closed removal of previous nails, reaming of marrow cavity as widely as possible, and reinsertion of stable intramedullary nail. Indications included femoral shaft aseptic nonunions with inserted intramedullary nail, nonunions with a radiolucent line, without segmental bony defects, and less than 1 cm shortening. They were followed up for a median of 2.9 (1–6) years. Thirty-three nonunions healed uneventfully within a median period of 4 (3–8) months. Except for three persistent nonunions, no other significant complications occurred.

Résumé Trente-six pseudarthroses de la diaphyse fémorale ont été traitées par ablation à foyer fermé du clou précédent, et ré – insertion d'un clou centro-médullaire stable en alésant la cavité médullaire aussi largement que possible. Les indications étaient les pseudarthroses de diaphyse fémorale aseptique avec clou centro-médullaire, les pseudarthroses avec persistance de la ligne fracturaire sans perte osseuse segmentaire, et avec moins d'un centimètre de raccourcissement. Ils ont été suivis avec une médiane de 2.9 (1–6) années. Trente-trois pseudarthroses ont guéri dans une période moyenne de 4 (3–8) mois. À l'exception de 3 pseudarthroses persistantes, aucune autre complication notable ne s'est produite.

Introduction

The concept of exchange nailing to treat delayed or nonunion of the femoral shaft has been advocated for several decades and a high success rate has been reported in the literature [4, 5, 10, 11]. However, skeptical results of this technique have also been reported [12]. Causes of failure in exchange nailing cannot be concluded concordantly,

possibly due to small sample sizes and large variations in injury severity among different series, [7, 12].

In this prospective study we treated femoral shaft aseptic nonunion with exchange nailing. The effect of this technique was reevaluated so that advantages or disadvantages might be further clarified.

Patients and methods

From October 1994 to December 1999, 39 consecutive adult (>15 years) patients with 40 femoral shaft aseptic nonunions were treated with exchange nailing at our institution. In this study a union was defined as a clinical state where there were no pain or tenderness, and patients could walk without aids. Radiographically, solid callus with cortical density had bridged fracture fragments. A nonunion was defined as a fracture that had not healed after 1 year of treatment or where a second operation was necessary to gain union. Patient ages ranged from 18 to 73 (median 32) years with a male-to-female ratio of two-to-one. Causes of nonunion were completely due to failed treatment of acute fractures that were all caused by vehicle accidents. All fractures were closed initially and the majority of nonunions were situated in the middle third of the shaft. The fractures had been operatively treated from one to four times during an interval of 0.5–9.0 (median 1.8) years. Previous implants consisted of plates and intramedullary nails. Techniques of the last operation included open Küntscher nailing (16), open static locked nailing (11), open dynamic locked nailing (9), closed dynamic locked nailing (2), closed static locked nailing (1), and closed Küntscher nailing (1) (Table 1). Five nonunions were associated with locked nail breakage, which included three cases after one-stage femoral lengthening [16]. All 40 nonunions were classified as atrophic. Indications for exchange nailing included aseptic nonunion with inserted intramedullary nails, nonunion with a radiolucent line, without segmental bony defects, and less than 1 cm shortening. History of wound healing process was carefully assessed and leg-length discrepancy was evaluated by measuring the spinomalleolar distance with or without the use of scanogram.

Surgical technique

First, patients were divided into two groups according to whether distal locked screws had to be inserted to achieve fragment stability. For those nonunions requiring no distal locked screw insertion, patients were anesthetized by spinal block and placed on the operating table in the lateral decubitus position. Skin incision was

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Table 1 Clinical data for 39 patients with 40 nonunions treated with exchange nailing. *A* upper third, *B* middle third, *C* lower third, *CDL* closed dynamic locked nailing, *CK* closed Küntscher nailing, *CSL* closed static locked nailing, *DK* double Küntscher

nailing, *DL* dynamic locked nailing, *F* female, *K* Küntscher nailing, *M* male, *ODL* open dynamic locked nailing, *OK* open Küntscher nailing, *OSL* open static locked nailing, *N* nonunion, *SL* static locked nailing, *T* lost follow-up

Case no.	Age	Sex	Fracture level	Previous number of operations	Method of last operation	Interval from injury (years)	Method of treatment	Over-reaming (mm)	Union period (months)	Complications	Follow-up (years)
1	18	M	B	1	CK	0.9	DL	1	4	–	6.0
2	31	M	B	1	CDL	4.5	DL	1	7	–	5.8
3	44	F	B	1	OK	1.0	DL	2	3	–	5.4
4	52	M	B	2	OSL	1.1	DL	2	4	–	5.0
5	62	M	B	1	OK	1.5	SL	2	T	T	T
6	26	M	B	1	OSL	2.0	DL	2	T	T	T
7	44	F	A	1	OK	2.0	DL	1	4	–	4.7
8	23	M	C	2	OSL	4.5	DL	1	N	N	4.5
9	73	M	B	1	ODL	3.0	SL	2	4	–	4.5
10	18	M	B	1	OK	0.8	DL	1	N	N	4.0
11	60	F	B	1	OK	2.0	K	1	T	T	T
12	19	M	A	2	OSL	8.0	DL	1	5	–	3.8
13	28	M	B	1	OK	1.5	K	1	4	–	3.5
14	66	M	B	2	ODL	2.0	DL	1	4	–	3.5
15	60	F	B	1	OK	1.8	SL	2	N	N	3.3
16	31	M	B	2	OSL	3.5	SL	1	5	–	3.3
17	22	M	A	2	ODL	3.0	DL	1	3.5	–	3.2
18	32	M	B	4	OK	2.0	K	1	4	–	3.0
19	28	M	B	1	OK	2.0	DL	2	3.5	–	3.0
20	60	M	B	1	ODL	1.6	DK	2	5	–	3.0
21	24	M	B	1	ODL	2.0	K	1	T	T	T
22	22	F	C	1	ODL	3.0	DL	1	6	–	2.9
23	36	M	B	1	OK	1.5	K	1	4	–	2.8
24	25	M	C	1	ODL	1.0	DL	2	8	–	2.8
25	73	M	B	1	OSL	5.0	DK	2	6	–	2.6
26	59	M	B	1	OK	0.6	DL	2	3.5	–	2.5
27	26	M	B	2	OSL	2.0	DL	2	4	–	2.4
28	40	M	B	1	OK	1.0	DK	2	4	–	2.4
29	36	M	B	4	OSL	9.0	DK	1	4	–	2.2
30	39	F	B	1	OSL	1.0	SL	1	5	–	2.0
31 ^a	61	M	B	3	OSL	3.0	DK	1	4	–	1.8
32	61	M	C	3	ODL	3.0	DL	2	4	–	1.8
33	38	F	B	1	OK	0.5	DL	1	6	–	1.7
34	29	F	B	1	CDL	3.0	K	1	5	–	1.6
35	25	M	B	1	OK	1.2	K	1	4	–	1.6
36	32	F	B	1	ODL	1.8	DL	2	4	–	1.5
37	24	F	B	1	OSL	1.0	SL	2	4	–	1.4
38	56	F	B	1	OK	0.8	DL	1	5	–	1.3
39	36	M	B	1	CSL	1.5	K	1	6	–	1.2
40	26	F	B	1	OK	0.6	DL	1	3.5	–	1.1

^a Case numbers 31 and 32 – same patient with bilateral nonunions

made on the buttock and the previous implant was removed, as was the previous nail. After a flexible guide wire was inserted into the distal fragment the marrow cavity was reamed as widely as possible until strong resistance was felt. In these patients only 1 or 2 mm overreaming was done then a 1-mm smaller size of single Küntscher nail (Zimmer, Warsaw, Indiana, USA), double Küntscher nails, or a proximally dynamic locked nail (Howmedica, Kiel, Germany), was inserted.

For those nonunions requiring distal locked screw insertion patients were generally anesthetized with intubation and placed on the fracture table in the lateral decubitus position. A 2.4-mm Kirschner wire was inserted in the femoral condyle for skeletal traction. The previous implant was removed and a flexible guide wire was inserted. The marrow cavity was similarly reamed as widely as possible. A 1-mm smaller size locked nail with distal locked assembly was then inserted. When 2-mm overreaming was done and a 1-mm smaller size locked nail was unavailable, static locked nail was inserted.

Postoperatively, patients were permitted to ambulate as early as possible with protected weight bearing. Quadriceps and knee range-of-motion exercise was encouraged. They were followed up at the outpatient department at 4- to 6-week intervals. Clinical and radiographic fracture healing processes were recorded. Aids could be discontinued only when bony union was achieved.

Results

Thirty-five patients with 36 femoral nonunions were followed up for at least 1 year (range 1.1–6.0, median 2.9 years). Four patients with four nonunions were lost to follow-up, despite all efforts. Thirty-three nonunions healed, with a union rate of 33/36 and a union period of median 4 (range 3–8) months (Figs. 1, 2, 3, and Table 1).

Fig. 1 Case 4: **a** A 52-year-old man sustained a right middle third femoral shaft comminuted fracture and was treated with plating at a local hospital. However, an atrophic nonunion with plate loosening occurred at 7 months. **b** The nonunion was treated with lengthening and stabilized with a static locked nail at our institution. **c** Double level nail breakage occurred at 6 months (*arrows*). **d** Exchange nailing with a distally locked nail was performed. **e** The fracture healed uneventfully at 4 months

Fig. 2 Case 16: **a** A 31-year-old man sustained a left middle third femoral shaft fracture and was treated with open Küntscher nailing at a local hospital. A nonunion occurred and was treated with a static locked nail at the same hospital. An atrophic nonunion with distal locked screw breakage was noted at 3.5 years. **b** Exchange nailing with a static locked nail was performed at our institution. **c** The fracture healed uneventfully at 5 months. **d** A good remodeling was noted at 3.3 years.

Fig. 3 Case 20: **a** A 60-year-old man sustained a left middle third femoral shaft fracture and was treated with open proximally locked nailing at a local hospital. An atrophic nonunion occurred at 1.6 years. **b** Exchange nailing with double Küntscher nails was performed at our institution. **c** The fracture healed uneventfully at 5 months. **d** A good remodeling was noted at 3 years

There were no perioperative complications and all patients could be discharged within 5 days postoperatively.

Complications included three aseptic nonunions. All three patients were followed up only because no symptoms were noted and they hesitated to undergo reoperation. There were no wound infections or malunions (defined as angulation $>10^\circ$, rotation $>10^\circ$, or shortening >2 cm) noted. No statistical difference could be achieved for nonunion type, fracture level, assembly of nails, and smoking history as described in the literature.

Discussion

The reported success rate of exchange nailing to treat femoral shaft delayed or nonunion is 53–100% [4, 12, 15]. Advantages of exchange nailing have been advocated. A small incision wound for nail inlet and requiring no exploration of nonunion site can shorten the operating time and diminish the complication rate. However, the maximal size of bone defects suitable for this technique has yet to be clarified. Clinically, it seems impossible to use patients for testing. Factors favoring fracture healing are minimal gap, adequate stability, and sufficient nutrition supply [8]. Because the size of bone defects can affect union rate, open bone grafting should be considered if any doubt exists [15]. In this study only nonunions with a radiolucent line were treated. While there was no detailed description about bone defects in previous series [4, 5, 10, 11, 12], theoretically, the amount of reaming bone graft should be not copious as it will affect union rate [8].

When a nonunion occurs and a radiolucent line is noted the gap should have been occupied by connective tissue. Overreaming of 1 or 2 mm can deposit only a small amount of cancellous bone along the reamed tract. Theoretically, fracture level will not affect the deposit of bone graft. In this study and in the literature results are concordant. Fracture level is not related to persistent nonunion [7, 12]. On the other hand, overreaming just 1 or 2 mm of the marrow cavity can achieve a high union rate; the amount of bone graft need not be great.

Although a dynamic locked nail can provide the compressive force and promotes fracture healing [13], there is no difference between a static and dynamic mode of exchange nailing. With a cancellous bone graft to promote fracture healing the added compressive force does not seem critical [3, 14]. This study and the literature arrived at similar conclusions [5, 7, 12].

Using a reamed intramedullary nail to treat a femoral shaft fracture usually can achieve sufficient stability. Unless Küntscher nail migration or nail breakage occurs in the early stage, all nonunions should be classified as atrophic. Therefore, cancellous bone grafting is always necessary to provide osteogenic power. In this study all nonunions were classified as atrophic, which are different from those in previous series [4, 10, 11, 12].

Although smoking has been considered to interfere with fracture healing or nonunion treatment in some lit-

erature reports [1, 7, 9], other studies doubt its negative effect [5, 6, 12]. Patients with persistent nonunion in this study were asked about their smoking history. Two patients denied smoking and one admitted to it. We found no difference between smokers and nonsmokers in this study.

Methods for treating persistent nonunion after exchange nailing are many and all methods have individual merits and defects. Repeated exchange nailing has been reported with success and the technique is the simplest [11]. However, due to the relatively small sample size the definite effect should be reevaluated. Open bone grafting can be considered and the effect may be satisfactory [15]. As for conversion to plating, a large wound with extensive soft tissue dissection may introduce more complications. In my opinion, plating is better preserved in the distal femur, where a locked nail easily breaks [2].

In conclusion, the present study revealed that exchange nailing can achieve a high success rate in the treatment of femoral shaft aseptic nonunion with indications. From theoretical and clinical considerations it should be the simplest technique among various treatment modalities and has the lowest complication rate. Therefore, it can be considered as the first choice in the treatment of indicated cases of nonunion. Nonunion rate with this technique is so low that factors inducing a persistent nonunion cannot be concluded from this study. Relatively larger sample sizes are necessary to investigate those factors and, clinically, it seems difficult to collect sufficient cases for such a study.

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