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Original article

Factors affecting peri-implant fracture following locking plate for osteoporotic distal femur fractures

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ABSTRACT

Introduction: The purpose of this study is to evaluate the outcomes and to analyze the risk factors for the occurrence of peri-implant fracture after treatment of osteoporotic distal femoral fractures using a locking plate.
Hypothesis: Risk factors affecting peri-implant fracture exist after locking plate fixation in osteoporotic distal femur fracture.
Materials and methods: Eighty-nine cases (88 patients) with osteoporotic distal femoral fractures were evaluated between January 2006 and January 2014. The cohort included 13 men and 76 women with a mean age of 70.4 (50–91). Mean duration of follow-up was 47.9 months (12 to 106). All patients with distal femoral fracture were treated with a locking compression plate. Bone mineralized densitometry measurement was obtained from all patients. Risk factors including sex, age, rheumatoid arthritis (RA), taking of bisphosphonate, primary or periprosthetic fracture after total knee arthroplasty (TKA), open or closed fracture, types of the most proximal screw (locking/cortical), and number of proximal screws were analyzed. Complication, union, time to union, and range of motion of knee were also evaluated.
Results: All patients had osteoporosis with the mean BMD of −3.16 (−2.5∼−5.4). The mean range of motion of knee was 126 degrees (90–145). Eighty-four cases (94.4%) showed union, the mean time to union was 14 weeks (10–42). Peri-implant fractures occurred in four patients (4.5%) after bone union at mean 37.5 months (14–62) postoperatively. Eight patients had angular deformities of over 5 degrees. Nonunion was observed in 5 cases and superficial wound infection in 2 cases. There were eight patients with RA, two of whom had suffered a peri-implant fracture. In statistical analysis, rheumatoid arthritis or periprosthetic fracture in TKA patients was a risk factor for peri-implant fracture ($P = 0.039$, 0.019, respectively), and other factors showed no statistical differences.
Conclusions: Treatment using a locking plate showed favorable outcomes in osteoporotic distal femoral fractures. However, peri-implant fracture could occur in patients with RA or periprosthetic fracture after TKA. Therefore, cautious consideration is required for management of osteoporotic distal femur fracture in patients with RA or periprosthetic fracture after TKA. Analysis of more cases will be needed in order to achieve conclusive results.
Level of evidence: Therapeutic study, level IV (retrospective study). See the Guidelines for Authors for a complete description of levels of evidence.

1. Introduction

In orthopaedic and trauma surgery treatment of distal femur fracture in osteoporotic patients is a challenge. The distal third of the femur is involved in approximately 6% of femur fractures [1] with more than 50% of fractures occurring in patients with osteoporosis [2]. High risk of failure and poor bone quality, which causes deficient implant fixation, rather than soft tissue or the fracture

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Table 1
Type of fracture and patient demographics.

Type of fracture [no. (%) of cases]	
Closed/open fracture	
Closed	81 (91)
Open	8 (9)
Primary/periprosthetic fracture	
Primary	56 (63)
Periprosthetic fracture after TKA	33 (37)
Mean age [range, (yr)]	70.4 (50–91)
Male	68.2 (64–89)
Female	71.0 (50–91)
Sex [no. of cases]	
Male	13
Female	76
BMD [*T*-score]	−3.16 (−2.5∼−5.4)
Male	−2.88 (−2.6∼−3.1)
Female	−3.21 (−2.5∼−5.4)
Implant [no.]	
LCP-DF (Synthes®)	76
ZPLP-DF (Zimmer®)	13

type, are the primary problem [3]. These problems were addressed with the recent development of the locking compression plate. Use of a locking plate provides the following advantages: preservation of periosteal blood supply, effectiveness of load transmission to the plate, stability for angular and axial load, and low risk of nonunion [4]. Therefore, the locking compression plate can provide better fixation in osteoporotic bone and lower rates of fixation failure in osteoporotic distal femoral fractures [5]. However, we have experienced the peri-implant fracture through the outermost screw hole of the locking compression plate after fracture union. Although infrequent, revision surgery may be required for these peri-implant fractures, thus they are a serious clinical concern [6]. Therefore, we evaluated the outcomes of osteoporotic distal femur fracture using a locking compression plate, and the risk factors associated with peri-implant fracture. Various surgery- and patient-related factors and characteristics of fractures were considered.

2. Materials and methods

The study was approved by the institutional review board of our hospital and all patients provided informed consent. Between January2006 and January 2014, osteoporotic distal femur fractures were treated with internal fixation at three tertiary referral hospitals. Bone mineralized densitometry (BMD) was evaluated in all patients. Surgically treated distal femur fractures classified as type 33 with AO/OTA classification were identified retrospectively. Cases with non-locking plate, double-plating techniques, other fracture on the ipsilateral lower extremity fracture, and less than 1 year follow up were excluded. A total of 88 patients (89 cases) were included in this study. All patients had undergone surgery with a distal femur locking compression plate, using a minimally invasive technique. All procedures were performed by three trauma surgeons. The study subjects included 13 males and 76 females of mean age 70.4 years (50 to 91 years) at index operations. Mean duration of follow-up was 47.9 months (12 to 106 months), and there was no expired case during the follow up period (Table 1).

During the operation, patients were placed in the supine position with a roll under the ipsilateral knee. The operation was performed on a standard orthopaedic table with either skeletal or manual traction. The standard lateral approach was performed in distal femur fracture without articular involvement and the lateral parapatellar approach was performed in intra-articular distal femur fractures. We checked alignment of rotation and axis, and length with an image intensifier and comparison of contralateral lower extremity. A LCP-DF (Synthes, Oberdorf, Switzerland) was used in 76 cases and a ZPLP-DF (Zimmer, Warsaw, India, USA) in 13 cases. The plate is fixed in the submuscular area between vastus lateralis muscle and periosteum using a minimally invasive technique.

For rehabilitation, patients were given instructions on how to perform quadriceps setting exercises after the operation. Active or passive range of motion exercises of hips and knees were encouraged as soon as possible. Patients were allowed to stand with partial weight bearing from callus formation on any one radiograph. Full weight-bearing was allowed after visible callus formation on both anteroposterior and lateral radiographs.

Complication, union, time to union, and range of motion of knee were evaluated during the regular follow up period and the last follow up. We assessed the clinical and radiographic outcome and the risk factors for occurrence of peri-implant fracture after treatment of osteoporotic distal femoral fracture using a locking compression plate. We performed statistical analysis of the risk factors including sex, age, rheumatoid arthritis (RA), taking of bisphosphonate, primary or periprosthetic fracture after primary TKA, open or closed fracture, number of proximal screws, and types of the outermost proximal screw (locking/cortical).

Statistical analysis was performed using the Mann-Whitney and Fisher's exact test. Statistical significance was accepted for P values of < 0.05, and SPSS version 16 (SPSS, Chicago) was used throughout.

3. Results

All patients were diagnosed with osteoporosis. The mean T-score of BMD was −3.16 (−2.5∼−5.4). Eighty-four cases (94.4%) showed union after the index operation. The mean time to union was 14 weeks (10–42 weeks). The mean range of motion of knee was 126 degrees (90–145 degrees). Seventy-three cases (82%) achieved pre-injury range of motion on knee. Nonunion was observed in 5 cases. All nonunion patients underwent revision surgery performed with change of plate and autogenous iliac bone graft. Although 8 patients showed an angular deformity over 5 degrees, these patients had no difficulty in performance of daily activities. Two cases of superficial wound infection were treated with irrigation, debridement, and intravenous antibiotics.

Peri-implant fractures occurred in four patients (4.5%) after bony union at mean 37.5 months (14–62) postoperatively. The peri-implant fracture occurred by low energy trauma such as slip and without obvious trauma. All peri-implant fractures occurred at the fixation site of the outermost proximal locking screw, and showed a transverse or short oblique pattern through the screw hole. Two peri-implant fractures were operated with a longer locking compression plate, and another two fractures with a cephalomedullary intramedullary nail (Fig. 1).

Various factors were thought to affect peri-implant fracture after distal femur fracture during the follow up period and we performed statistical analysis of the risk factors.

According to sex, although all periprosthetic fractures occurred in 4 females, there was no statistical difference between male and female (P = 1.000). The mean age was 68.5 years (61–72) in the peri-implant fracture group and 70.4 years old (50–91) in the non-fracture group, with no statistical difference (P = 0.681). There was no statistical difference between continuous taking of bisphosphonate and non-taking group (P = 0.293). There was no statistical difference between open and closed fracture (P = 1.000). The number of proximal screws did not affect the occurrence of peri-implant fracture (P = 0.573). The type of the outermost proximal screw (locking/cortical) was not a risk factor associated with peri-implant fracture (P = 0.573). Among our cohort, eight patients had RA, two of whom had suffered a periprosthetic fracture (P = 0.039). In statistical analysis, rheumatoid arthritis was a risk factor for periprosthetic fracture. All peri-implant fractures

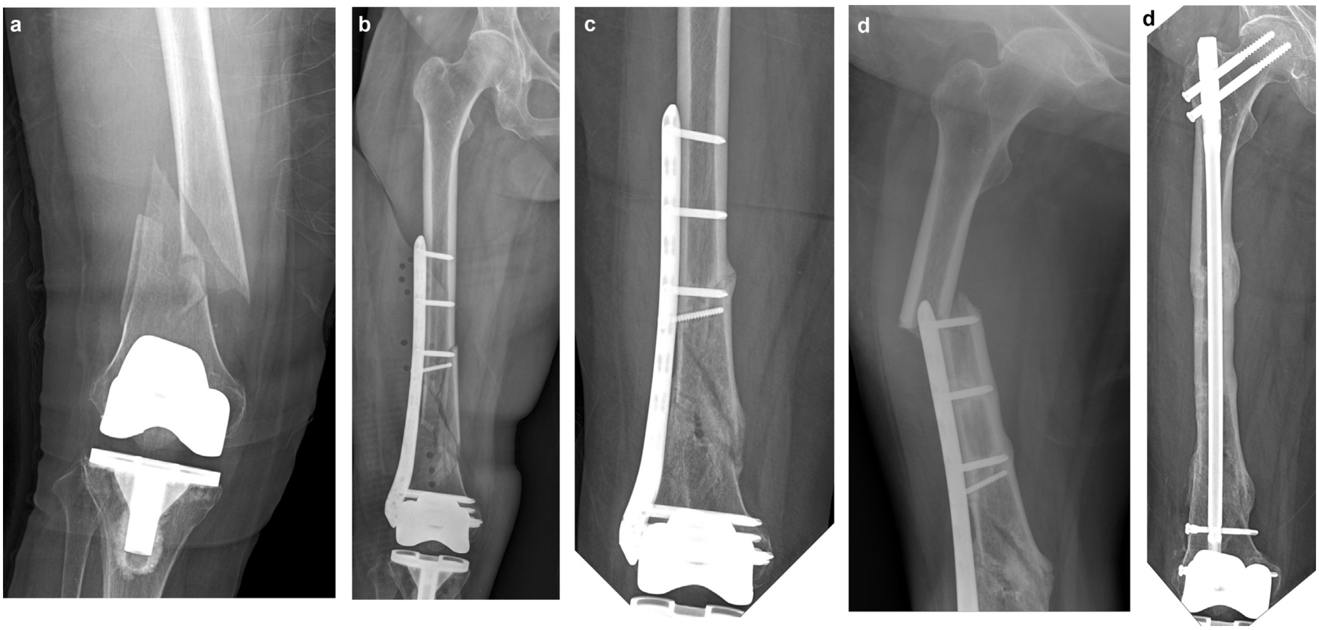

Fig. 1. a: a 72-year-old female sustained a distal femoral periprosthetic fracture; b: locking compression plate fixation was performed using a minimally invasive technique; c: anteroposterior radiograph shows bony union at 12 months postoperatively; d: at 15 months after the operation, she had a peri-implant fracture through the outermost screw hole; e: intramedullary nailing was performed after removal of the plate, final radiograph shows bony union.

Table 2
Analysis of risk factors associated with peri-implant fracture.

	Peri-implant fracture ($n = 4$)	Non-fracture ($n = 85$)	P
Mean follow-up (month, SD)[a]	59.3 (37.98)	47.8 (23.94)	0.461
Patient-related factor			
Sex (men: women)[b]	(0: 4)	(13: 72)	1.000
Mean age (year, SD)[a]	68.5 (5.20)	70.4 (9.35)	0.681
RA (RA: non-RA)[b]	2: 2	6: 79	0.039
Bisphosphonate[b] (taking: non-taking)	2: 2	22: 63	0.293
Characteristics of fracture			
Periprosthetic: primary fracture[b]	4: 0	29: 56	0.019
Open: closed fracture[b]	0: 4	8: 77	1.000
Surgical-related factor			
Outermost proximal screw[b] (Cortical: locking screw)	0: 4	25: 60	0.573
Mean number of proximal screws (SD)[a]	4 (0)	4.2 (0.76)	0.573

SD: standard deviation; RA: rheumatoid arthritis.
[a] Mann-Whitney test.
[b] Fisher's exact test.

occurred in patients with periprosthetic fracture after primary TKA. All existing TKA implants were used a conventional prostheses without femoral stem or constraints. And periprosthetic fracture after TKA was a risk factor for peri-implant fracture ($P = 0.019$, Table 2).

4. Discussion

Treatment of distal femur fractures in patients with osteoporosis is a challenge. Many problems with earlier implants were alleviated with the use of a distal femoral locking compression plate [5]. Locking plates provide more stable fixation due to better angular stability and pullout-resistance of locking screws, especially in metaphyseal fixation of osteoporotic bone [5,7]. Therefore, favorable outcomes have been reported in the treatment of osteoporotic distal femoral fractures using a locking compression plate. However, locking plates do not solve all problem in osteoporotic distal femoral fracture [8], a recent study on locking plates reported a 2.6% incidence of peri-implant fracture at the end of the plate [9]. Also, we have experienced four peri-implant fractures (4.5%) after treatment with a locking compression plate for osteoporotic distal femur fracture. Therefore, we evaluated the factors affecting peri-implant fracture following locking compression plate for osteoporotic distal femur fractures.

The peri-implant fracture at the plate end is a well-known complication associated with plate fixation in osteoporotic bone [10]. The reported incidence rate of peri-implant fracture after conventional compression plating is 1% to 3% [6]. Some authors have attributed peri-implant fractures to the stress concentration effect at the plate end; the stress increases with increasing distance from the fracture site, with most of the load transfer occurring through the outermost screws [11,12]. Difference in stiffness between the patient's bone and the plate-fixed bone segment can be another cause [13]. This difference in stiffness is particularly appeared in osteoporotic bone, where stress concentrations at the outermost screw hole increase the risk of peri-implant fracture [14].

In our study, all peri-implant fractures occurred through the outermost screw hole suggesting that a locking end screw induces a stress concentration like conventional plating. Using conventional plates, the plate is kept closed to the bone, and load transfer through the screws as well as through the plate to bone contact surface. On the other hand, when using a locking plate, the load transfer occurs through locking screws without load transmission between plate and bone interface [14]. Therefore, compared with a conventional plate, higher stress convergences caused by the load transfer through locking screws may be induced with use of a locking plate. In previous study, Harkess and Ramsey [10] recommended unicortical fixation of the outermost screw in a conventional plate to reduce these peri-implant fractures. However, other studies reported that unicortical end screws caused an increase in the stress riser effect at the outermost screw hole [6,13], thus fixation using a unicortical end screw is no longer performed. One study recommended use of oblique screws at the end of plate to avoid peri-implant fracture [15]. Another mechanical study reported on conventional screw fixation at the end of the plate, which reduced the stress concentration at the plate end compared with all locking screws [14]. In this study, our cohort included both conventional and locking screw fixation at the outermost screw hole and those two types of screw fixation were compared. Although we expected that the two types of screw fixation would differently affect to the risk of occurrence of peri-implant fracture, there was no significant difference between fixation with a conventional and locking screw at the end of the plate. However, all peri-implant fractures occurred in patients with the outermost locking screw, these outcomes are thought to be due to small number of peri-implant fractures. Therefore, we suggest that a case study of large number for type of screw fixation is necessary. We evaluated the surgical-related factor according to the number of proximal screws. There was no association with number of proximal screws because we believe that it has been fixed with four or more screws in the proximal fragment.

In addition, we analyzed the risk factors associated with peri-implant fracture in terms of patient-related factors. In occurrence of peri-implant fracture, there was no association with sex, age, and taking of bisphosphonate. These findings are thought due to the fact all patients were diagnosed with osteoporosis and possessed similar quality of bone. However, RA was a risk factor for peri-implant fracture ($P = 0.039$). Systemic bone loss in patients with RA is multifactorial, including taking of glucocorticoids, decreased physical activity, and the disease itself [16]. Hyperosteoclastosis in RA can be explained by the major role of proinflammatory cytokines, based in mechanism involved in bone loss [17]. We thought that RA affected decrease of bone quality and stress concentration effect through the outermost locking screw may be emphasized in RA patients.

According to characteristics of fracture, there was no association between open and closed fracture. Although open fracture could increase early complication such as infection, it did not affect peri-implant fracture as a late complication. In terms of primary or periprosthetic fracture after TKA, periprosthetic fracture is associated with peri-implant fracture ($P = 0.019$). After TKA, mean bone density loss of approximately 15% was reported in the distal disphyseal area, beside the metaphyseal area. These reductions of BMD were observed at the distal 1/3 of the femur around periprosthesis [18], however we thought that the loss of bone density at the distal femur could affect plate construction and this weak construction would lead to peri-implant fracture after locking compression plate for osteoporotic patients.

In our study, we have not found deep infection, no loosening of the implant, or metal failure of plate. To avoid infection after operation, we thought that soft tissue management is important, especially in open fracture or periprosthetic fracture after TKA. Therefore, we performed a minimally invasive operation as possible to minimize damage of soft tissue. All fractures were fixated with bridging plate method, and longer plates were used as possible. These operation methods might effect on the outcome without other complications.

In addition, there was no up-to-date report on timing of periprosthetic fracture. In this study, the periprosthetic fracture occurred at mean 37.5 months (14–62) postoperatively. It can be assumed that there may be a risk of periprosthetic fracture until the locking plate has been removed [14]. However, in removal of the locking plate and screws there is a concern regarding secondary fracture through the empty screw hole in osteoporotic bone. Therefore, to reduce peri-implant fracture after locking compression plating in osteoporotic distal femur fracture, additional mechanical study for type of screw and fixation method would be necessary.

5. Conclusion

Treatment using a locking plate showed favorable outcomes in osteoporotic distal femoral fractures. However, peri-implant fracture could occur in patients with RA or periprosthetic fracture after TKA. Therefore, cautious consideration is required for management of osteoporotic distal femur fracture in patients with RA or periprosthetic fracture after TKA.A study including a large number of cases will be necessary in order to confirm the conclusive result.

Ethical Board Review statement

This study was approved by the Institutional Review Board at our institute. All patients gave their informed consent before their inclusion in the study.

Disclosure of interest

The authors declare that they have no competing interest.

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