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ORIGINAL ARTICLE

Is internal fixation using a reversed condylar locking plate useful for treating Vancouver type B1 periprosthetic femoral fractures?

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Abstract
Purpose The aim of this study is to investigate clinical result and complication with locking compression plate-distal femur (LCP-DF) for Vancouver type B periprosthetic fracture and compared to standard conventional locking plate.
Patients and methods Twelve patients treated using reversed LCP-DF were compared with 12 treated using broad LCP. As radiographic evaluation, the period of bone union, and the numbers of screws and cables that were used with each plate were compared between the two groups. The complications, operation time, blood loss, and clinical assessment were investigated.
Results The number of locking screws that could be inserted into the proximal fragment was 5.83 (4–8) in the LCP-DF group and 2.25 (1–4) in the Broad LCP group, being significantly greater in the former (p=0.00003). Post-operative complications were observed in two patients, of whom one in the broad LCP group showed delayed healing after reduction loss, and the other in the LCP-DF group showed skin irritation symptoms in the plate application area. There was no significant difference in the mean operation times (p=0.81), the mean blood losses (p=0.47), and the walking ability (p=0.95) between the two groups.
Conclusions We showed that higher number of screws was inserted with reversed LCP-DF without any adverse event. This technique is safe with no inferior clinical outcome to standard locking plate.

Keywords Periprosthetic femoral fracture · Locking compression plate · Vancouver classification · Osteoporotic bone

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Introduction

Periprosthetic femoral fracture occurs rarely and the incidence is reportedly about 0.1–4.2 %, but it has been rising as artificial hip joints have been increasingly applied and with the aging of the population [1–4]. The treatment becomes more difficult compared to normal femoral fracture because of the following reasons: (1) Bone union is not readily achieved because the first surgery impairs medullary blood flow. (2) Screw fixation is poor because of the vulnerability of the bone. (3) Intramedullary nailing is not applicable because the stem occupies the marrow cavity and screw placement is difficult [5]. Although the locking plates are considered biomechanically advantageous for osteoporotic bone [6], the clinical usefulness of the locking plates for the periprosthetic femoral fracture is still controversial [7–11]. In particular, in Vancouver type B fractures [12], the main fracture line is proximal to the distal end of the stem; thus, rigid fixation for the proximal bony fragment gives great import on the successful treatment. However, commercially available locking compression plate may not be able to achieve enough rigid fixation. Broad locking compression plate (broad LCP: Synthes) system, which is standard commercially available, used for this type of fracture allows the combined use of screws and cables

(Fig. 1a, b). In this system, either the locking screw or the cerclage positioning screw, which is connected to a cerclage cable, can be inserted into one screw hole. Therefore, only a small number of locking screws can be inserted into the proximal bone fragment. This can give big influence on the undesired clinical outcomes, and higher number of screws in the proximal fragment is strongly desired. On the other side, the condylar locking plate (locking compression plate-distal femur: LCP-DF) is normally used for femoral supracondylar fracture and has seven screw holes in the plate portion applied to the femoral condyle. Thus, we made the hypothesis that the proximal bone fragment in Vancouver type B periprosthetic fracture can be fixed with many locking screws by reversing LCP-DF and applying it to the greater trochanter (Fig. 1c, d). The aim of this study is to investigate the number of inserted screws, clinical result, and complication with LCP-DF for Vancouver type B1 periprosthetic fracture and compared to standard conventional locking plate.

Patients and methods

Between 2007 and 2011, we treated 69 periprosthetic femoral fractures, of which 27 Vancouver type B1 fractures were treated in our department (Fig. 2). In those, 24patients was operatively treated and included in this study, and 3 patients were treated non-operatively due to severe deteriorated general condition and excluded in this study. Surgically treated 24 patients consist of 12 patients by internal fixation with broad LCPs in 2007–2009 (broad LCP group) and 12 patients treated using reversed LCP-DF in 2009–2011 (LCP-DF group). Since 2009, LCP-DF has been consequently used for all patients. Between two groups, there is no difference in both groups in terms of age, gender, types of previous surgery, cement use, and ambulance ability before trauma (Table. 1). Two patients in broad LCP group had a dementia, none in LCP-DF group. Because LCP-DF has been used since 2009, follow-up period in broad LCP group is longer. The LCP-DF group consisted of 2 males and 10 females. The mean age at the time of the first surgery was 64.9 years (30–80 years), and the mean age at the time of injury was 73.6 years (47–86 years). The underlying disorder was femoral neck fracture in 6 patients, osteoarthritis in 5, an osteonecrosis of the femoral head in 1. The previous surgery was hemiarthroplasty in 7 patients and total hip arthroplasty in 5. In this group, the mean follow-up period was 2.8 years. The broad LCP group consisted of 3 males and 9 females. The mean age at the time of the first surgery was 69 years (55–81 years), and the mean age at the time of injury was 72.3 years (63–85 years). The underlying disease was femoral neck fracture in 7 patients, osteoarthritis in 14, and osteonecrosis of the femoral head in 1. The previous surgery was hemiarthroplasty in 8 patients and total hip arthroplasty in 4. Patients in the broad LCP group had an average follow-up of 4.8 years. Bone quality such as bone mineral density was not evaluated after the injury. However, the number of case having femoral neck fracture due to osteoporosis as original injury was almost the same (6 cases in LCPDF, 7 cases in Broad LCP). Also, the number of case having treatment history of osteoporosis was also the same (8 cases in each group). All 24 patients were followed-up by radiographic and clinical evaluation on an outpatient basis at intervals of 1 to 3 months until 1 year after the operation and at

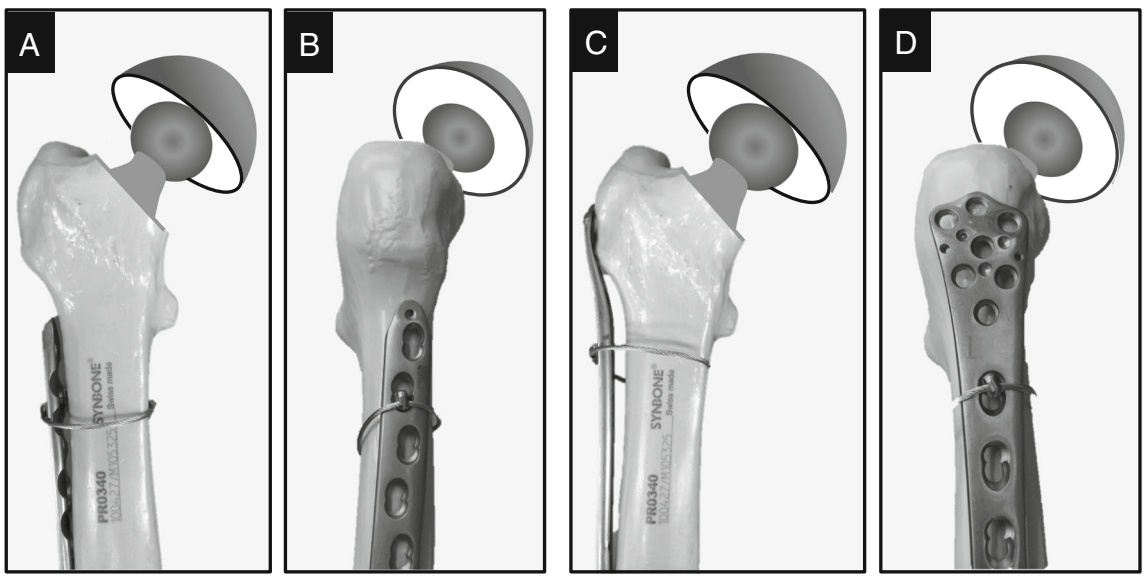

Fig. 1 The locking compression plate system. **a**, **b** In the broad LCP for Vancouver type B fractures, when multiple cerclage cables are used for the proximal bone fragment, only a few locking screws can be inserted into the proximal fragment. **c**, **d** In the LCP-DF, the shape and curve of the portion that contacts the condyle nearly fit the shape of the greater trochanter on the opposite side. Therefore, even cable fixation was combined with screw fixation, and an adequate number of screws could be inserted into the proximal bone fragment

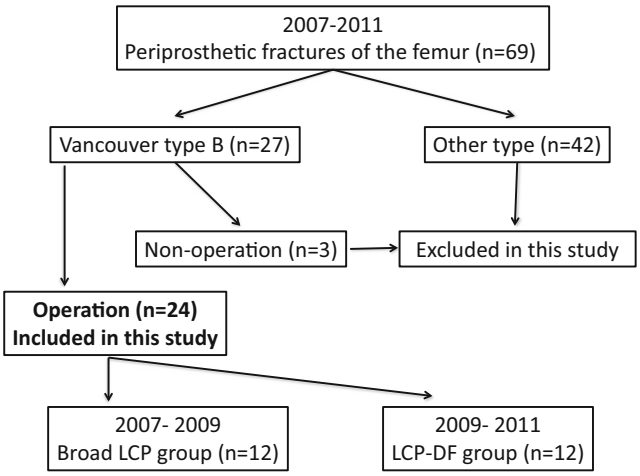

Fig. 2 Patient selection flow chart

intervals of 6 months thereafter. The evaluation was conducted by a senior surgeon (T.B) with non-blinded manner. As radiographic evaluation, the numbers of screws and cables that were used at each plate were compared between the two groups. Radiographic union was defined by evidence of bridging bone at two or more cortices on standard anterior-posterior and lateral radiographs. As clinical evaluation, intra- and post-operative complications, operation time, and intra-operative blood loss were investigated. For clinical assessment, pain and mobility were evaluated according to the scoring system of Merled'Aubigné and Postel [13]. In addition, walking ability [5] was assessed before injury and 1 year after surgery by categorizing into independent walking, walking with a cane, walking with two crutches, walking using a walker or while holding on to something in the house, and wheelchair use (unable to walk).

Table 1 Demographic characteristics of patients

	LCP-DF	Broad LCP	*p* value
Age (years)	73.6 (47–86)	72.3 (63–85)	0.6[b]
Male/female	2:10	3:9	0.62[a]
BHA/THA	7:5	8:4	0.67[a]
Cemented/uncemented	1:11	2:10	0.54[a]
Walking ability before trauma (number of patients)			
Independent walking	7	6	
With a cane	2	3	
Two crutches	2	1	
Using a walker	1	2	
Wheelchair use (unable to walk)	0	0	
Follow-up (year)	2.8 (2–4)	4.8 (4–6)	<0.01[b]

[a] Chi-squared test

[b] Student's *t* test

Surgical technique and post-operative care

Surgery was performed in the lateral position. After the fracture was exposed, the reduction was archived by minimum periosteal dissection and temporarily fixed by Kirschner wire (K-wire). The plate was aligned with the femoral axis by sliding it into the submuscular area of the vastus lateralis muscle. When the LCP-DF was used, the plate for the unaffected contralateral was used. The plate was reversed, and its distal part (originally, this part applied to the condyle) was placed so as to fit to the greater trochanter (Fig. 3). When the broad LCP was used, it was placed distally from the innominate nodule of the greater trochanter (Fig. 4). After temporary K-wire fixation, the plate was fixed to bone with cerclage cables at the area where the plate mostly contacted with proximal bone fragment. The locking screws were inserted to the proximal bone fragment as many as possible. The distal bone fragment was fixed with positioning screws, which was followed by fixation with locking screws.

The post-operative rehabilitation schedule included the initiation of partial weight-bearing after 6 weeks and full weight-bearing after 10 weeks in both group. For patients who could not perform partial weight-bearing because of dementia or an advanced age, full weight-bearing was permitted after 10 weeks.

Statistical analysis

Statistical analyses were performed with Statcel 2 software (OMS publishing Inc., Tokyo, Japan). The normal distribution and equal variance of the data were tested by the software. Continuous data were analyzed using Mann-Whitney *U* test and Student's *t* test, and data grouped into categories were analyzed with the chi-squared test. A p value <0.05 was considered significant.

Results

The number of locking screws that were inserted to the proximal fragment was 5.83 (4–8) in the LCP-DF group and 2.25 (1–4) in the Broad LCP group, being significantly greater in the former ($p<0.001$) (Table. 2). The number of screws inserted into the distal fragment was 4.17 (3–5) in the LCP-DF group and 4.0 (3–6) in the broad LCP group, showing no significant difference ($p=0.70$). The number of cerclage cables was 2.5 (2–3) in the LCP-DF group and 3.0 (2–4) in the broad LCP group, showing no significant difference ($p=0.1$). There were no intra-operative complications. Post-operative complications were observed in two patients, of whom one in the broad LCP group showed delayed healing after reduction loss, and the other in the LCP-DF group showed skin irritation symptoms at the plate application area on the lateral

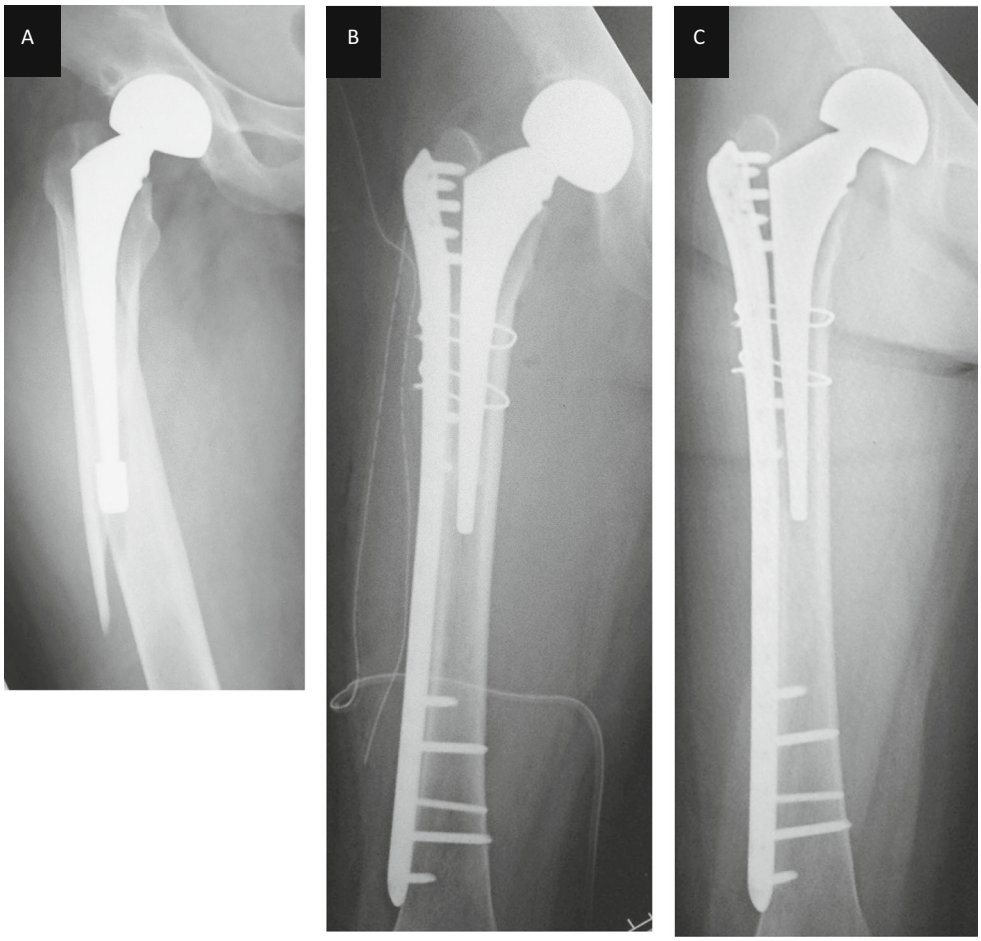

Fig. 3 Forty-six-year-old female. **a** X-ray radiography at the time of injury. Vancouver type B1 periprosthetic femoral fracture. **b** X-ray radiography immediately after surgery. Condylar LCP was reversed and internally fixed. **c** X-ray radiography 6 months after surgery. Bone union was achieved

side of the greater trochanter. In the patient showing delayed healing, varus deformity remained, and bone union required 18 months. The patient showing skin irritation was very thin and having rheumatoid arthritis. Since this patient had no clinical symptoms other than mild pain when lying in a lateral recumbent position on the affected limb, no surgical treatment was performed. There were no neurovascular injuries, deep vein thromboses, or superficial or deep infections. On the final follow-up, bone union was achieved in all patients. The mean operation times were 121.0 (90–135) and 123.3 (95–148) min in the LCP-DF and the broad LCP groups, respectively, showing no significant difference between the two groups (p= 0.81). The mean blood losses were 168.9 (70–250) and 229.0 (100–450) mL in the LCP-DF groups and the broad LCP, respectively, showing that it was smaller in the LCP-DF group, but the difference was not significant (p=0.47). The mean Merled'Aubigné and Postel hip score 1 year after surgery was 10.2 (pain 5.1, range of motion of the hip joint 5.1) in the LCP-DF group and 10.5 (pain 5.2, range of motion of the hip joint 5.3) in the broad LCP group, showing no significant difference between the two groups (p=0.67). Regarding walking ability before injury and 1 year after surgery (Fig. 5), four patients (33.3 %) recovered to the same level in the LCP-DF group, and the level declined by one grade in seven (58.3 %) and two grades in one (16.7 %). In the broad LCP group, five patients (41.7 %) recovered to the same level, and the level declined by one grade in five (41.7 %) and two grades or more in two (16.7 %). Combining the two groups, the level declined by two grades or more in three patients, comprised of two with dementia, one with rheumatoid arthritis, and one with post-brain infarction hemiplegia patients (overlapped). There was no significant difference in the walking ability between the two groups (p=0.95).

Discussion

The treatment for the Vancouver type B periprosthetic fracture is still a big challenge. The rigid fixation for proximal fragment is the key for success. The higher number of locking screw is strongly desirable, but it may not be possible with standard commercially available LCP plate in Japan. Thus, we made the hypothesis that reversed LCP-DF achieves higher number of screws inserted to the proximal fragment in the Vancouver type B fracture without any adverse event. And, we showed that higher number of screws was inserted with

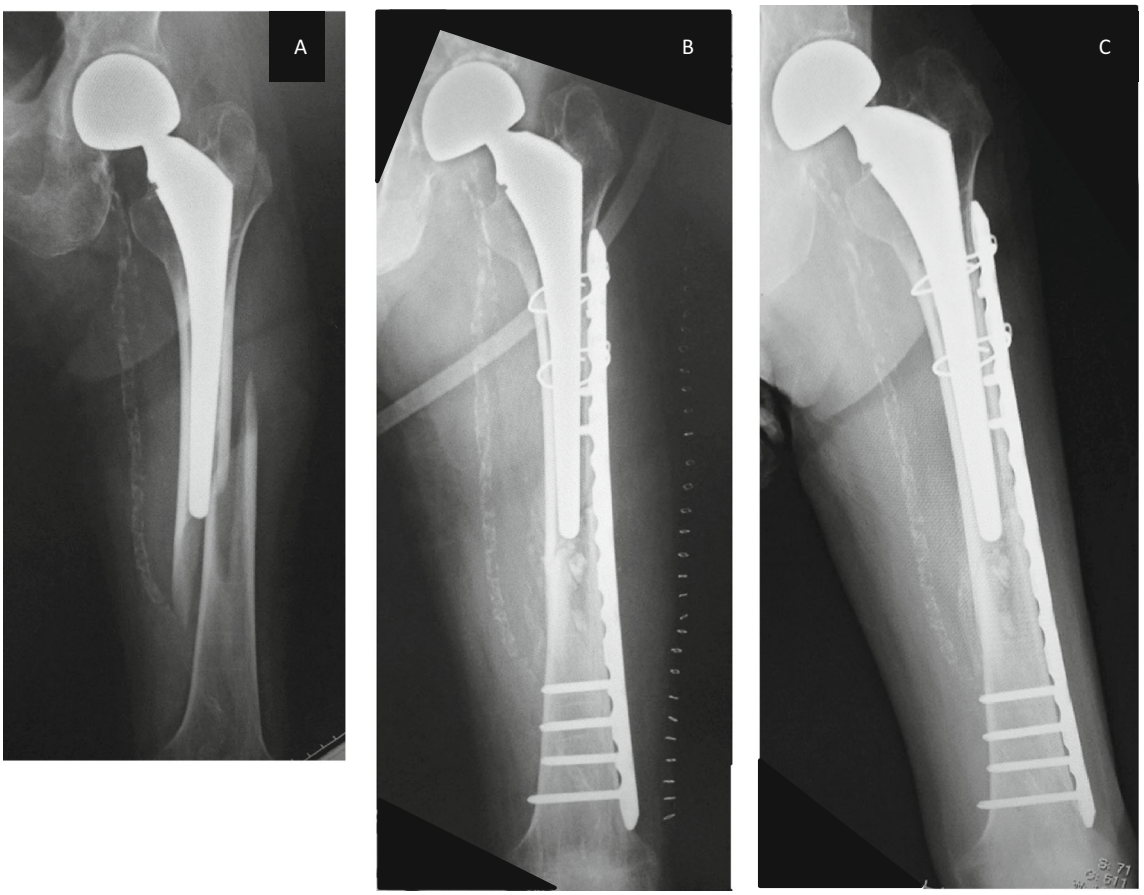

Fig. 4 Seventy-four-year-old male. **a** X-ray radiography at the time of injury. Vancouver type B1 periprosthetic femoral fracture. **b** X-ray radiography immediately after surgery. Broad LCP was internally fixed. **c** X-ray radiography 6 months after surgery. Bone union was achieved

LCP-DF without any adverse event. Also, we demonstrated no inferior clinical result with LCP-DF compared to broad LCP.

Concerning the limitations of this study, the number of the patient is obviously too small to show the benefit of our technique. However, we showed that higher number of screw was possibly inserted compared to standard LCP. And also, we were able to show no adverse event in reversed LCP-DF technique. In those reasons, we consider that our data still have a value. The second limitation is that the degree of the fixation by reversed condylar locking plate compared with the conventional Broad LCP for the femoral shaft is unclear. However, as the principal of screw fixation, it is clear that more screws can have more rigid fixation. Thirdly, this study is a retrospective non-blinded study. However, the operation and evaluation

Table 2 Comparison of patients treated by the LCP DF versus patients treated by the broad LCP

	LCP-DF	Broad LCP	*p* value
The number of screws			
Proximal fragment	5.8 (4–8)	2.3 (1–4)	<0.001[a]
Distal fragment	4.2 (3–5)	4.0 (4–8)	0.7[a]
The number of cerclage cables	2.5 (2–3)	3.0 (2–4)	0.1[a]
Operation times (min)	121.0 (90–135)	123.3 (95–148)	0.81[a]
Blood loss (mL)	168.9 (70–250)	229 (100–450)	0.47[a]

[a] Student's *t* test

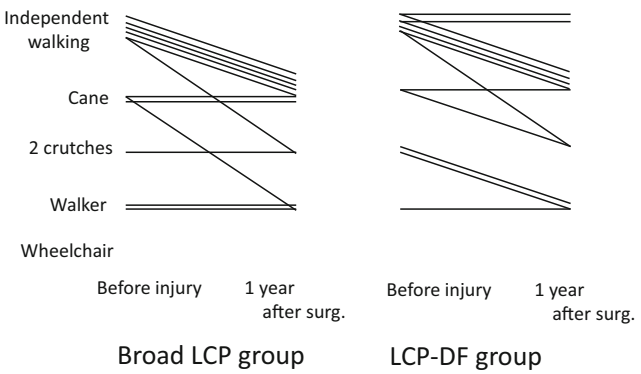

Fig. 5 Walking ability before injury and 1 year after surgery. In the LCP-DF group, four patients (33.3 %) recovered to the same level, and the level declined by one grade in seven (58.3 %) and two grades in one (16.7 %). In the broad LCP group, five patients (41.7 %) recovered to the same level, and the level declined by one grade in five (41.7 %) and two grades or more in two (16.7 %). There was no significant difference in the walking ability between the two groups

were performed by a single surgeon, and evaluated parameters were clear and simple; thus, biases seem to be relatively small.

Previously, for the treatment of periprosthetic femoral fractures, Duncan et al. recommended, according to Vancouver Classification, conservative treatment for type A, osteosynthesis or fixation with only allografts for type B1, revision surgery for type B2, the combination of these methods for type B3, and osteosynthesis for type C [12–15]. Their treatment strategies are widely used. However, despite the establishment of the treatment principles, it is difficult to have rigid fixation for the proximal bone fragment in the Vancouver type B; thus, the best surgical treatment for this type is still controversial. To the present, various methods have been performed: fixation is performed by wiring alone, regarding the stem as an intramedullary nail; fixation with a conventional plate and screws, and the combination of a conventional plate and screws cables [16–18]. We also reported the result of internal fixation using the conventional plate in combination with screws and cables giving favorable outcomes [5]. However, postoperatively relatively long period of non-weight-bearing restriction was necessary due to poor fixation at the proximal bone fragment; because the medullary cavity of the proximal main bone fragment is occupied by the stem, only unicortical screws can be used in many cases, which may decrease the rigidity of fixation. Also, in the case where the fixation for the proximal fragment is poor, the loss of reduction and implant failure might occur. Therefore, better clinical outcome demands the extent of rigidity for the fixation at proximal fragment. In recent years, locking plates with angle stability have been used for this type of fracture, and favorable results have been reported. But for type B fractures, even if locking plates are used, the degree of fixation for the proximal bone fragment may not be adequate. Buttaro et al. performed fixation for type B1 fractures using the LCP with locking screws without the combined use of cables, and observed plate breakage in 3 of 14 patients and screw loosening in 3 [10]. Demos HA et al. performed a basic experiment on the same type of fracture using cadavers and reported that proximal bone fragment fixation with 3 cortical screws alone provides weaker fixation than that with 3 cortical screws combined with 3 cables [19]. Based on these results, it is obviously desirable that as much number of locking screw as possible could be inserted at the proximal fragment in order to augment the fixation. Therefore, in this study, we used LCP-DF for this type of fracture and showed more locking screws were inserted compared to broad LCP. Indeed, in the broad LCP group, when 2–3 cables were used for the proximal bone fragment, only 2.25 screws could be inserted, and there were only a few patients in whom the proximal bone fragment could be fixed with 3 cables and 3 screws as in the above basic experiment. In the LCP-DF, the shape and curve of the portion that contacts the condyle nearly fit the shape of the greater trochanter on the opposite side. Therefore, even cable fixation was combined with screw fixation, and an adequate number of screws could be inserted into the proximal bone fragment. As a result, we could fix the proximal bone fragment with 5.8 (4–8) locking screws without reducing the number of cables. This method can increase the fixation where broad LCP is not able to archive. As a consequence, the patient in the broad LCP group showed delayed healing after reduction loss due to an inadequate fixation. But, none in the LCP-DF group showed reduction loss. We observed one patient in the LCP-DF group with skin irritation caused by the plate in the greater trochanter. We think very thin subcutaneous fat due to rheumatoid arthritis is the reason for the irritation. After this case, we apply the LCP-DF for thin patient at slightly distal part of the greater trochanter. And, none of skin irritation has been occurred. This technique achieved more screws simply reversed the pre-existing plate without obvious adverse event. This technique is sate and can be an alternative method for Vancouver type B1 periprosthetic femoral fractures. In further study with large number, the effectiveness of this technique is needed to evaluate.

Conflict of interest None

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