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ORIGINAL STUDY

Treatment of distal femur fractures with locking plates : Comparison of periprosthetic fractures above total knee arthroplasty and non-periprosthetic fractures

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The purpose of the present study was to compare the results and plate fit of periprosthetic and non-periprosthetic distal femur fractures fixed with locking plates. Twenty-one periprosthetic fractures above a TKA and 27 non-periprosthetic fractures were retrospectively reviewed. The primary healing rate, bone union time, clinical and radiographic results, complications, and additional surgeries were compared between the two groups. The quality of the plate fit on the bone was also compared. There were no differences in the primary healing rate, bone union time, clinical and radiographic results between the two groups. The incidence of overall complication and additional surgeries did not differ (3/21 vs. 5/27, 1/21 vs. 4/27). Plate fit trouble was observed more frequently in periprosthetic fractures (10/21 vs. 1/27, p = 0.004). Fixation of distal femur fractures with locking plates provided satisfactory results with a low risk of complications and additional surgeries in both periprosthetic and non-periprosthetic fractures.

Keywords : distal femur fractures ; locking plate ; total knee arthroplasty ; periprosthetic ; non-periprosthetic.

INTRODUCTION

The surgical treatment of distal femur fracture using anatomically pre-shaped locking plates has been popularized because of its biomechanical advantage and technical ease (*13,25,31*). The pre-shaped plate can indirectly reduce the fracture fragments with good alignment and can enable surgeons to maintain the biologic microenvironment for fracture healing (*20,25*). The locking screw fixation is particularly advantageous in increasing mechanical stability to allow for early mobilization and preventing screw loosening, especially in osteoporotic bone and for comminuted fractures (*3,32*). The use of locking plates for periprosthetic fracturesabove total knee arthroplasty (TKA) has theoretical advantage overcoming the poor bone quality and trouble of screw purchase in the elderly patients with TKA prosthesis (*16,17,25*). To our knowledge, there have been no studies comparing the clinical results between periprosthetic and non-periprosthetic fractures with an attempt to clinically prove this theoretical advantage.

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Generally, the pre-shaped plate does not require further contouring. Osteoarthritic patients may have combined conditions such as severe diaphyseal bowing, and the TKA prosthesis may block ideal positioning of the plate on the lateral cortex of distal femur in the sagittal plane. However, it is unknown whether the pre-shaped locking plate properly fits in the distal femur fracture above TKA.

The purpose of the present study was to evaluate a consecutive series of periprosthetic and non-periprosthetic distal femur fractures using a pre-shaped locking plate and to compare the results between two groups with regard to the primary healing rate, bone union time, clinical and radiological results, complications, and additional surgeries. Another purpose was to compare the plate fit radiographically between periprosthetic and non-periprosthetic fractures.

Our hypothesis was that the result of periprosthetic fracture using the pre-shaped locking plate would show comparable results to the non-periprosthetic fracture about the variables above. Another hypothesis was that the plate fit in periprosthetic fractures might be different from that in non-periprosthetic fractures.

MATERIALS AND METHODS

Patients

All patients who had been treated for a distal femur fracture with pre-shaped locking plate between 2008 and 2012 were retrospectively reviewed. The locking plate used was a locking compression plate-distal femur (LCP-DF, Synthes, Paoli, PA). The inclusion criterion for periprosthetic fracture was a distal femur fracture without loosening of the prosthesis. The exclusion criteria for periprosthetic or non-periprosthetic fractures were non-surgical treatment, the internal fixation using the other fixatives besides locking plates, intramedullary rigid or flexible nail fixation, intraoperative fracture during TKA, and pathologic fracture except osteoporosis. Forty-eight patients were included and were followed up for a minimum of 12 months postoperatively. There were 21 periprosthetic fractures above a TKA and 27 non-periprosthetic fractures. The demographics of the 48 patients are shown in Table I. There were no significant differences between the two groups in terms of age, gender, right and left sides, body mass index, severity of injury, interval between the fracture and operation, or follow-up periods (Table I). In the periprosthetic fractures, causes for TKA included osteoarthritis in 12 patients, rheumatoid arthritis in 6 patients, post infectious arthritis in 2 patients, and hemophilic arthropathy in 1 patient. Types of prostheses included Press fit condylar (Johnson & Johnson, Raynham, MA) in 10 knees, NexGen (Zimmer, Warsaw, IN) in 5 knees, Ortholoc (Dow Corning Wright Medical, Arlington, TN) in 2 knees, and others in 4 knees. According to the Lewis and Rorabeck classification (*26*), all fractures were type II. According to the Neer classification (*7*), ten fractures were type II, 8 fractures type III, and 3 fractures type IV.

Healing rate and bone union time

Patients were contacted on a regular basis. The postoperative physical and radiographic examinations were performed at 1, 2, 3, 6 and 12 months and annually there-

Table I. — Demographics of periprosthetic and non-periprosthetic fractures

Fractures	Periprosthetic	Non-periprosthetic
Patients (number)	21	27
Age (years) (SD, range)	68.0 (9.1, 53-86)	63.4 (17.9, 18-89)
Female/male (number)	19/2	20/7
Right/left (number)	13/8	17/10
Body mass index (kg/m^2) (SD, range)	26.3 (5.4, 18.4-36.9)	26.7 (5.5, 19.1-38.1)
Severity of injury (low-/high-energy trauma)	20/1	23/4
AO/OTA classification* (A1/A2/A3/C1/C2/C3)	9/6/4/1/1/0	4/3/7/6/4/3
Interval between fracture and operation (days)(SD, range)	3.5 (2.2, 0-9)	4.2 (3.4, 0-13)
Follow-up period (years) (SD, range)	2.5 (2.1, 1.1-5.9)	2.7 (2.9, 1.2-5.9)

*AO/OTA classification, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association classification.

after. The primary healing rate was evaluated as the bony union rate without any additional surgery. The bone union time was evaluated among the patients who showed primary healing. The radiographic bone union was defined as those with callus formation, cortical bridging of more than half of visible cortices on the anteroposterior, lateral and oblique radiographs. The clinical bone union time was defined as those without pain at weight bearing or without tenderness at the fracture site (21). The primary healing rate, radiographic, and clinical bone union time (months) were compared between the periprosthetic and non-perirprosthetic fractures (21).

Clinical evaluation

The Knee Society knee score was used to evaluate pain, including range of motion (ROM), just before the fracture and in the latest follow-up period for the periprosthetic fractures (19). The knee score before the fracture for the non-periprosthetic fracture was substituted to the knee score in the opposite side because the patients did not visit our hospital before the fracture. The ROM was measured using a long-armed goniometer.

Radiographic evaluation

Serial preoperative and postoperative anteroposterior, lateral, and oblique views of the femur and knee were obtained and reviewed to assess callus formation, loss of reduction, and limb alignment (9). Radiographic measurements were taken using the picture acquiring communication system (PACS), and it could allow measurement to one decimal point. Radiographic results were evaluated with respect to the femorotibial angle (FTA) on the prefractue (periprosthetic fractures) or the opposite side (non-periprosthetic fractures), 2-week-postoperative, and latest follow-up radiographs (Fig. 1). The coronal and sagittal angles at the fracture site were measured on the 2-week-postoperative and last follow-up radiographs (Fig. 2). The component position was evaluated only for the periprosthetic fractures. The α and γ angles were defined as the coronal and sagittal femoral component angles, respectively (9). Those angles were measured on the 2-week-postoperative and last follow-up radiographs

To reduce any observation bias, two independent investigators made all of the radiographic measurements. The intra- and inter-observer reliabilities of the measurements were assessed using the intraclass correlation coefficient (ICC). In this study, the ICCs for all measurements were greater than 0.85 for the intra- and interobserver reliabilities. The FTA, coronal angulation, and sagittal angulation were compared between the two groups.

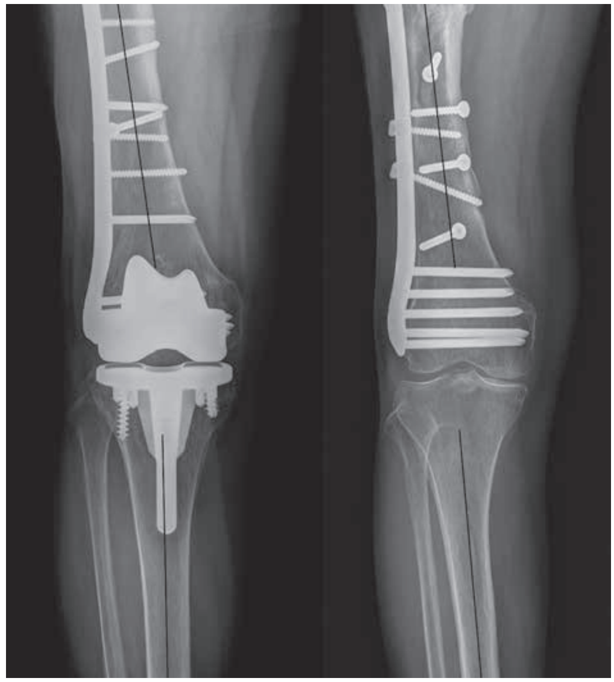

Fig. 1. — The femorotibial angle (FTA) was measured. The radiographs of knee were checked including enough portions of the diaphysis of the femur and tibia to draw the anatomical axes. The anatomical axis of the femur was defined as the line connecting the center of the medullary canal 10 cm and 20 cm proximal from the femoral condyle. The anatomical axis of the tibia was defined as the line connecting the center of the medullary canal 10 cm and 20 cm distal to the tibial plateau. The FTA was measured based on these femoral and tibial anatomical axes.

Complications and additional surgeries

Complications in the form of nonunion, malunion, infection, hardware failure, loss of reduction and others were recorded. Nonunion was defined as no callus formation until postoperative 6 months or fracture of the plate after postoperative 6 months. Malunion was defined as a shortening of > 2 cm, coronal angulation of > 5°, or sagittal angulation of > 10° (8,30). Hardware failure included any metal breakage of the plate or screw before postoperative 6 months. Loss of reduction was defined as changes in the coronal and sagittal alignment of > 3° before union (16). Any kind of medical complication was assessed as well.

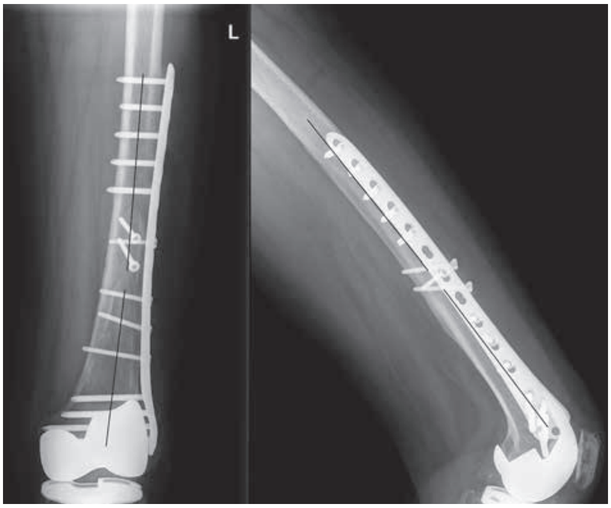

Fig. 2. — The coronal and sagittal angulation of the fracture site was measured to evaluate loss of reduction such as that seen in varus/valgus or flexion/extension angulation on the 2-week postoperative and follow-up radiographs.

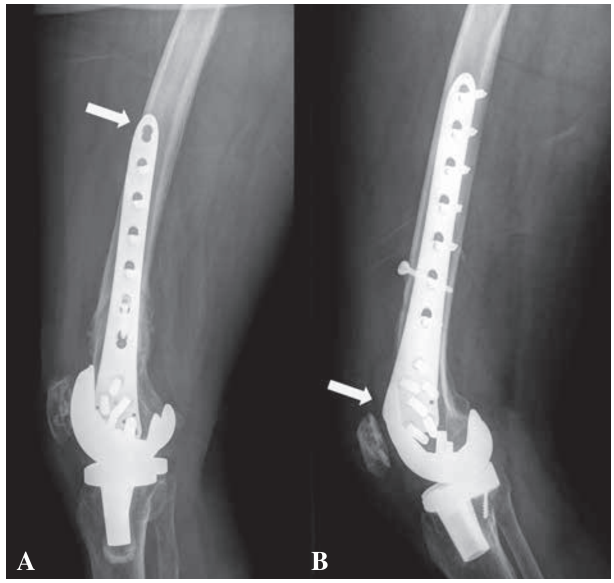

Fig. 3. — The quality of the plate fit on the host bone was evaluated. The proximal fit trouble was defined to be positive when the proximal end screw insertion was difficult or impossible (A). The distal fit trouble was defined to be positive when the insertion of any distal locking screw insertion was impossible due to blockage by the TKA prosthesis or limitation of contact between the plate and femoral condyle (B).

Subsequent additional surgeries were recorded, including revision open reduction and internal fixation (ORIF), and bone grafting.

Plate fitting

The quality of the plate fit on the host bone was compared between the periprosthetic and non-periprosthetic fractures. Proximal fit trouble was defined to be positive when the proximal end screw insertion was difficult or impossible because of the limitation of contact between the lateral femoral cortex and proximal portion of LCP-DF (Fig. 3A). The distal fit trouble was defined to be positive when the TKA prosthesis blocked the usual positioning of the LCP-DF on the lateral femoral condyle or when the insertion of any distal locking screw was impossible (Fig. 3B).

Surgical technique

All ORIFs were carried out by single surgeon. All exposures were performed through a lateral approach. The basic principle was similar for both periprosthetic and non-periprosthetic fractures with a biological surgical technique in which the approach to the fracture site was sparingly dissected (*2,8,20*). The distal portion of lateral femoral condyles and the fracture site that required visibility for reduction were exposed, but the posterior and medial soft tissues of the fracture site were not violated. Reduction of the fragments was achieved in a combined direct/indirect manner, often with the aid of an anatomically pre-shaped plate (*2,18,20*). The distal locking screws were inserted as many as necessary. The proximal screws were inserted with a hybrid technique selectively using locking or non-locking cortical screws (*10*). The locking screws were used with expectation of increasing mechanical stability, especially under axial compression. The non-locking screws were used considering plate contact to the host bone, additional effect of fracture reduction and the increasing effect of the plate bending strength. Isometric exercises were initiated shortly after the operation. On postoperative day 3, active and assisted knee ROM exercises were initiated. Patients were mobilized based on the degree of bone quality, severity of injuries, and pattern of fractures. At postoperative day 5 to 6, the patients were mobilized with crutches until 6 weeks. Full weight-bearing ambulation without any aids was started at approximately 3 months to the extent that the patient's condition permitted.

Statistical analysis

The study was approved by the institutional review board. Informed consent was obtained from all patients before the review, and no patient refused to participate. Bone union time and clinical and radiographic results were compared between the periprosthetic and non-periprosthetic fractures (Student t-test). The primary healing rate, complications, additional surgeries, and plate fitting were compared between the two groups using the chi-square test. Statistical analysis was performed using the SPSS version 18.0 software (SPSS Inc., Chicago, IL), and p values < 0.05 were considered to indicate statistical significance.

RESULTS

Primary healing rate and bone union time

Twenty of 21 periprosthetic fracturesand 26 of 27 non-periprosthetic fractures healed without any further surgery (*n.s*) for the bone union. The average radiographic bone union times were 4.7 ± 2.8 months in the periprosthetic fractures and 4.8 ± 2.9 months in the non-periprosthetic fractures (*n.s*). The average clinical bone union times were similar between the two groups (4.2 ± 2.6 months in the periprosthetic fracturesvs. 4.2 ± 2.5 months in the non-periprosthetic fractures, *n.s*).

Clinical and radiographic results

There were no differences between the two groups in the knee score and ROM (*n.s*) (Table II).

The radiographic results showed that preoperative varus deformity was greater in non-periprosthetic fractures (Table III), and the surgical reduction was aimed to the original alignment just before fracture. The postoperative alignment after ORIF using LCP-DF was sustained until the last follow-up, and the loss of reduction was minimal in both periprosthetic and non-periprosthetic fractures (Table III). For the postoperative component position of the periprosthetic fractures, α and γ angles were 95.2° ± 2.2° and 2.5° ± 2.5°, respectively. At the last follow-up, the position of implant was unchanged with α angle of 95.1° ± 2.4° and γ angle of 1.6° ± 3.5°, respectively.

Complications and additional surgeries

The incidence of overall complication and additional surgeries was not different between periprosthetic and non-periprosthetic fractures (*n.s*) (Table IV). One of 21 periprosthetic fractures developed a nonunion leading to hardware failure. It was successfully treated with revision ORIF using LCP-DF with autogenous and allogenous cancellous bone grafts. One loss of reduction with varus angulation occurred during bone union, but no additional surgery was performed. Deep vein thrombosis occurred in one patient and was treated conservatively. Among the 27 non-periprosthetic fractures, there were two refractures after primary bone healing and removal of internal devices. One hardware failure occurred at postoperative 3 months. They were successfully treated with revision ORIF using LCP-DF with autogenous and allogenous cancellous bone grafts. One malunion with valgus deformity was corrected with osteotomy and fixation with anangled blade plate at the original fracture site to relieve the patient's gait discomfort.

Table II. — Clinical results according to types of fractures among patients healed primarily

Fractures		Periprosthetic	Non-periprosthetic	P-value
Knee score*	Before fracture	90.7 ± 3.6	91.3 ± 4.5	0.594
	Last follow-up	84.3 ± 8.3	87.2 ± 5.3	0.164
	Change	-6.4 ± 8.2	-4.1 ± 4.6	0.183
Range of motion (degrees)	Before fracture	111.4 ± 25.2	112.2 ± 20.9	0.948
	Last follow-up	98.6 ± 28.7	102.8 ± 29.3	0.643
	Change	-12.8 ± 18.3	-9.4 ± 11.9	0.468

*Knee score, Knee Society knee score.

Table III. — Radiographic results according to types of fractures

Fractures		Periprosthetic	Non-periprosthetic	P-value
FTA* (degrees)	Before fracture or opposite side°	Valgus 6.3 ± 2.8	Valgus 3.0 ± 2.7	< 0.001
	Postoperative	Valgus 5.2 ± 4.1	Valgus 2.5 ± 4.6	0.043
	Last follow-up	Valgus 5.6 ± 4.3	Valgus 2.8 ± 4.5	0.043
Coronal angle•	Postoperative	0 ± 2.9	Varus 0.7 ± 2.5	0.390
	Last follow-up	Valgus 0.2 ± 3.5	Varus 0.4 ± 1.9	0.480
Sagittal angle•	Postoperative	Extension 0.6 ± 2.6	Flexion 0.7 ± 3.3	0.144
	Last follow-up	Flexion 0.1 ± 2.0	Flexion 1.1 ± 2.3	0.110

*FTA, femorotibial angle; •Coronal or sagittal angle, varus and valgus angle or flexion and extension angle at the fracture site; °Before fracture or opposite side, radiographic varibales before fracture for the periprosthetic fracture or radiographic variables of the opposite side for the non-periprosthetic fracture.

Table IV. — Comparison of complications between periprosthetic and non-periprosthetic fractures after internal fixation using locking plates

Fractures	periprosthetic	Non-periprosthetic
Number of total patients	21	27
Number of primary healing difficulties	1	1
Number of overall complications	3	5
Nonunion	1*	0
Malunion	0	1•
Infection	0	0
Hardware failure	0	1*
Loss of reduction	1	0
Refracture after removal of internal devices	0	2*
Deep vein thrombosis	1	0
Pulmonary embolism	0	1

*, additional surgeries performed like revision open reduction and internal fixation and bone grafting; •, additional surgery performed like corrective osteotomy and revision open reduction and internal fixation after primary healing of fracture site.

Plate fitting

Plate fit trouble was observed in 10 fractures among 21 periprosthetic fractures and one fracture among 27 non-periprosthetic fractures ($p = 0.004$) (Fig. 3). Among 10 plate fit troubles in periprosthetic fractures, there were 4 proximal fit troubles, 5 distal fit troubles, and one proximal and distal fit trouble. The one plate fit trouble in non-periprothetic fractures was distal fit trouble.

DISCUSSION

The most important finding of the present study was that the results of surgical treatment using a locking plate in periprosthetic distal femur fractures were as satisfactory as in non-periprosthetic fractures with a low risk of complications and additional surgeries. Although a locking plate leads to greater stability and endures higher loads until hardware failure than a conventional plate (2,22), several recent studies has reported about the failure of the locking plate (*11,15,16,24*). They have insisted that displaced fracture gap and increased stiffness provided by the locking plates may lead to nonunion or delayed union (*10,12*). Other clinical studies have expressed concerns about hardware failure (*15,29*). One previous meta-analysis showed that the overall rate of healing difficulties including nonunion or delayed union and hardware failure widely ranged from 0% to 32% in distal femur fracture treated with locking plates (*13*). This kind of variation in healing difficulties seems to be caused by the definition of failure and heterogeneity of the data. For example, Schutz *et al* (*27*) reported nonunion rate of 3%, but the delayed union rate, additional bone grafting, hardware failure and overall healing difficulties were 10%, 10%, 5% and 28%, respectively. Several clinical studies might be based on results from multiple surgeons to gather enough cases of distal femur fractures using a single fixative (*14,27,28*). But, the analysis of heterogenous or selective data could not represent the real estimation of primary healing rate because many surgeons have their own individual surgical principles and techniques. It is necessary to perform analysis on consecutive cases with a consistent principle for surgical technique and postoperative management carried out by single surgeon. In addition, to our knowledge, only one previous study (*13*) showed its data with differentiation of the periprosthetic and non-periprosthetic fractures. We tried to analyze a consecutive series of cases performed by a single surgeon and compare the variables including primary healing, complication, and additional surgeries rates between periprosthetic and non-periprosthetic fractures. The primary healing rates without any further surgery were 95.2% (20/21 fractures) in periprosthetic fractures and 96.3% (26/27 fractures) in non-periprosthetic fractures. Another variables including bone union time, complication and additional surgeries of the present study were also satisfactory when compared with recent reports (*16,23,25*). We believe that specific surgical principles and tips should be followed during treatment of distal femur fractures to increase the advantage of locking plates. The reduction resulting from use of biological surgical technique (*2,8,24*) is beneficial because a small fracture gap (< 1 mm) combined with a dynamic osteosynthesis technique favors fracture healing (*1,8*). The hybrid technique can combine the advantages of locking and non-locking screws (*5,10,25*) to improve mechanical stability, plate contact to the host bone, and indrect reduction of the fracture.

The use of the locking plate for the periprosthetic fracture above TKA has theoretical advantage overcoming the poor bone quality and trouble of screw purchase in elderly patients with TKA prosthesis (*6,33*), and we had as satisfactory results as in non-periprosthetic fractures with a low risk of complications and additional surgeries. However, we have several concerns about the types and periods of complication. One patient had nonunion in periprosthetic fracture combined with hardware failure after postoperative 8 months after ORIF using a locking plate in spite of sufficient initial mechanical stability and satisfactory reduction of fracture (Fig. 4). We think that hardware failures occurred secondarily to an established nonunion in which the fixatives experienced loading cycles exceedingits fatigue limit and the case was categorized not to hardware failure but to nonunion (*3,13,15*). Also, we don't think that nonunion of this patient would have successfully healed through increasing stability of fracture site or delayed rehabilitation. Effort should focus on enhancing the biologic microenvironment, and efforts promoting earlier and more callus formation like initial bone graft could have been performed. One patient had loss of reduction in periprosthetic fracture after postoperative 3 months. We think that it could have been prevented through delayed rehabilitation or locking screw fixation of proximal main fragment placed adjacent to the fracture site (*4*).

Two patients had refractures in non-periprosthetic fracture after primary healing and removal of internal devices (Fig. 5). Each fixative was removed at postoperative 2.3 years and 2.2 years to prepare the ongoing TKA after radiographic and clinical bone union without additional surgeries for fracture healing. Refractures were occurred at 2 months later after removal of internal devices. We think that it would have been preventable through TKA without removal of internal device using navigation or extramedullary femoral guide. Among non-peripros-

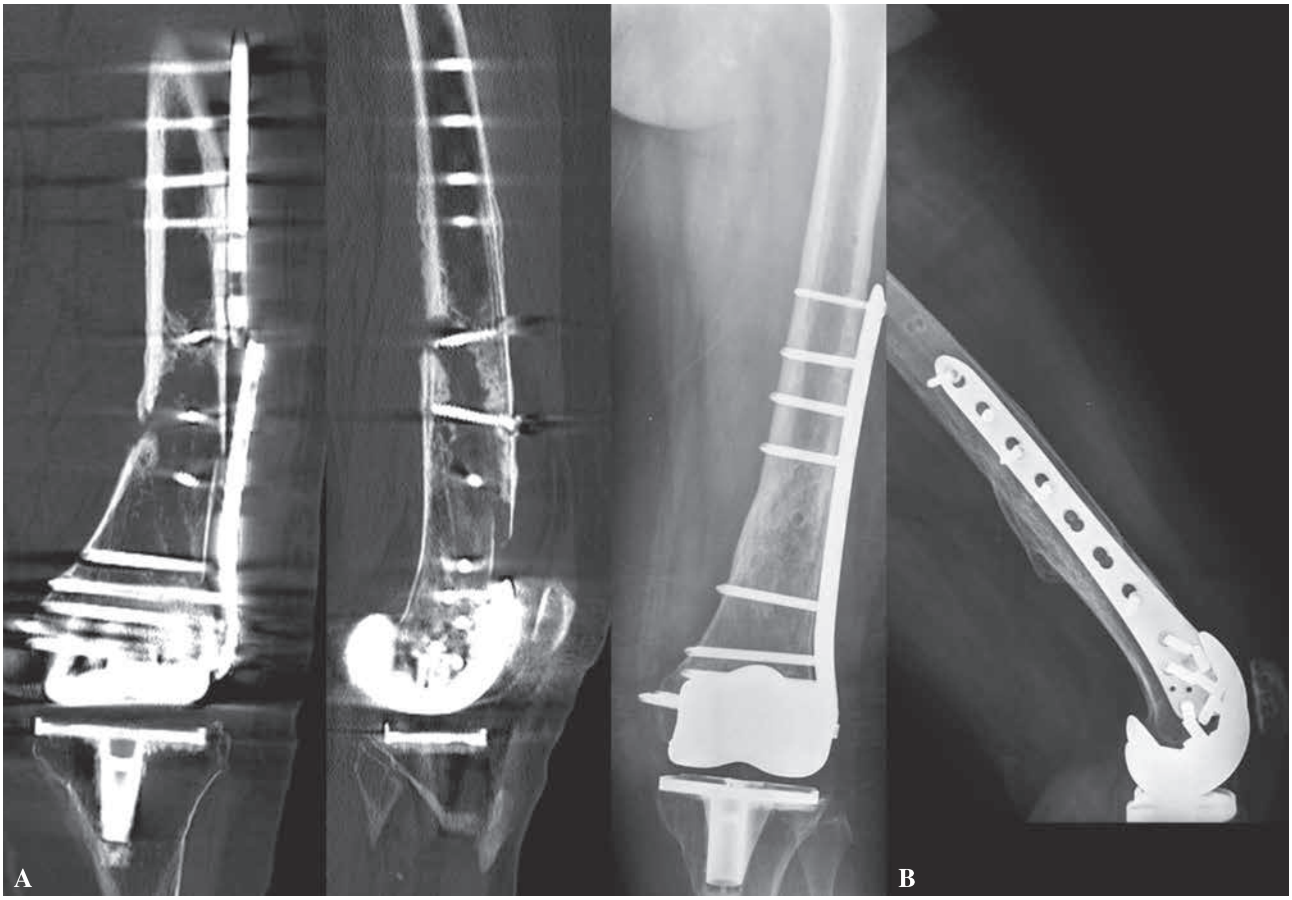

Fig. 4. — The hardware failure developed secondary to nonunion at 8 months after locking plate fixation (A). This patient was successfully treated with revision open reduction and internal fixation with bone grafting (B).

thetic fractures, one patient with severe comminuted supracondylar femur fracture and osteoporosis had hardware failure at postoperative 2 months. We think that it could have been prevented through delayed rehabilitation. One patient had valgus malunion in non-periprosthetic fracture which could have been prevented through proper initial reduction. It was corrected through following corrective osteotomy. After the review of the present series, we could build the concept that all complications related to bone union in non-periprosthetic fracture were preventable through prohibition of fixative removal and modification of rehabilitation protocol. We also realized the importance of the biological surgical technique overcoming poor bone quality and severe comminution in elderly patients with periprosthetic fracture.

The other purpose of the present study was to compare the quality of the locking plate fit on the host bone between periprosthetic and non-periporsthetic fractures. The fit trouble was observed in a considerable proportion of periprosthetic fractures (47.6%, 10/21 fractures), but not generally observed in non-periprosthetic fractures. One previous study reported the typical pattern of mismatch of Asian femur at the proximal part of the 11 hole LCP-DF, which was developed based on skeletal measurements in Caucasians (*18*). However, this type of mismatch does not have a great clinical significance because LCP-DF does not necessarily need to be compressed against the host bone with the possible use of the locking screws. The coronal varus bending at the level of 8^{th}-9^{th} combination holes can also solve the mismatch (*18*). We were rather concerned

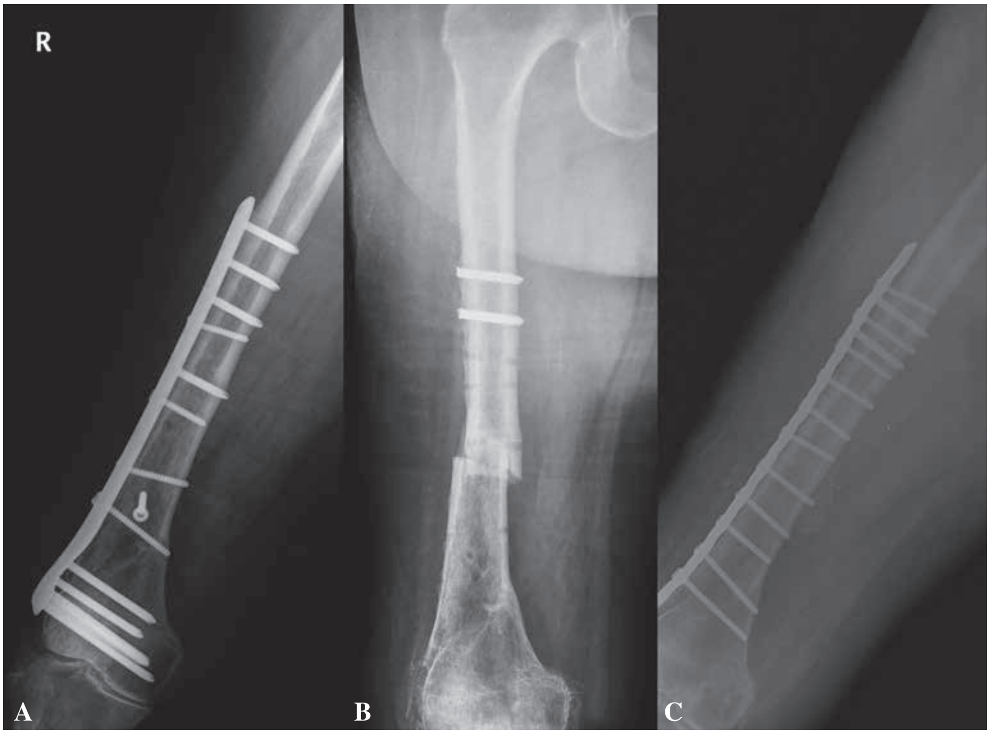

Fig. 5. — Among non-periprosthetic fractures, two patients had refractures after primary healing and removal of internal devices at postoperative 2.2 years to prepare the ongoing TKA (A). Refractures were occurred at 2 months later after removal of internal devices (B). The revision open reduction and internal fixation with bone grafting was performed (C).

about the sagittal fit trouble of the LCP-DF in the periprosthetic fractures, because it can't be overcome easily. When the LCP-DF is applied to the bone in periprosthetic femur fractures, the distal part of the plate is easily displaced posteriorly due to the effort associated with multiple locking screw fixation in the short distal condyle and the blocking of the anterior flange of the femoral component (*2*). It displaces the proximal part of the locking plate anteriorly and makes it difficult to usea sufficient number of proximal screw fixation. If both proximal and distal parts of a locking plate are forced to contact to the bone in periprosthetic comminuted femur fractures, it happens to result in posterior angulation of the fractures. Sufficient understanding of this phenomenonwill help to ease proper placement of the long plate. Because the prominence of fixatives to the bone can also make irritating symptoms that require removal (*31*), further anatomical studies combined with innovation of fixative design may be necessary to improve the plate fitting in periprosthetic distal femur fractures.

The present study was limited by its retrospective design and the small sample size. It has strength in the prospective collection of consecutive patients and in the lack of follow-up loss. Another strong point is the comparative analysis of two types of fractures. The knee score and ROM were superior in non-periprosthetic fracture with low risk of plate fit trouble, but there was no statistically significant difference between the two groups. This finding could be explained by the insufficient power with small number of subjects or by the ceiling effect of the Knee Society scoring system. It may not be sensitive enough to discriminate between small difference in pain and function. We think that the prospective randomized trial with large sample size would be necessary to detect the amount of clinical importance in relation to the plate fit trouble.

CONCLUSION

Fixation of distal femur fractures with a locking plate provided satisfactory results with high rate of primary healing and with a low risk of complications and additional surgeries in both periprosthetic and non-periprosthetic fractures. However, pre-shaped locking plates specific for the periprosthetic fracture may need to be developed for better plate fitting.

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