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Are proximal screws necessary for osteosynthesis of stable-stem periprosthetic femoral fractures fixed with non-locking plate and cable? ☆

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ABSTRACT

Introduction: The purpose of this study was to assess the effectiveness of the cable-plate-cable technique which comprises fixation of the proximal fragment using cable loops without additional proximal screws on the plate for the treatment of stable-stem periprosthetic femoral fractures around hip prostheses.
Methods: We retrospectively reviewed Vancouver types B1 and C periprosthetic femoral fractures treated with a dynamic compression plate combined with Dall-Miles cable between 2010 and 2016 at a single institution and followed for at least 12 months. Patients were treated with proximal fragment fixation using cable combined with screws (Group I) or with proximal fragment fixation using cable alone (Group II). Demographic data, fracture types, and clinical and radiological outcomes were analyzed.
Results: A total of 50 patients were included (Group I, n = 23 patients; Group II, n = 27). Fracture union was achieved in 49 patients with one case of non-union in Group I and no cases of non-union in Group II. Mean time to union was 5.4 months in Group I and 5.1 months in Group II (P = 0.624). Mean Harris hip score at latest assessment was 69.5 in Group I and 69.4 in Group II (P = 0.919). Regarding complications, there was one deep wound infection, one stem subsidence, and one loss of reduction in Group I, and one stem subsidence in Group II. No significant difference in clinical and radiological outcomes between groups was observed.
Conclusions: The cable-plate-cable technique sufficiently treats Vancouver types B1 and C periprosthetic femoral fractures without use of additional screws in the proximal fragment.

Introduction

The rising prevalence of hip arthroplasty has led to an increase in periprosthetic femur fractures worldwide [1]. Patients who have suffered a periprosthetic fracture have significantly increased morbidity and mortality, and the outcomes in these patients are heavily influenced by the treatment protocol [2]. Technical challenges arise in the treatment of periprosthetic fractures due to the presence of the femoral stem prosthesis, poor muscle condition, and soft tissue contracture. In addition, these fractures often occur in elderly patients who have osteoporotic bone, making stable fixation more problematic [3].

The Vancouver classification developed by Duncan and Masri [4,5] grades periprosthetic femur fractures based on fracture location, prosthesis stability, and bone quality. This validated classification scheme is the most well-accepted system for grading periprosthetic femur fractures after hip arthroplasty [6], and serves as a useful guide for treatment. For fractures occurring around a well-fixed stem (Vancouver type B1) or distal to the stem (Vancouver type C), open reduction and internal fixation (ORIF) is the recommended procedure [3,7,8].

While there are several methods for ORIF of periprosthetic femur fractures, no single method has gained universal acceptance.

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The more commonly described ORIF techniques include the use of cortical strut allografts, cable plate/compression plates with or without allograft struts, and locked plating [9]. The presence of the prosthesis in the proximal medullary canal and poor bone quality resulting from periprosthetic osteopenia pose challenges in achieving stable fixation proximally [10]. Cables are typically supplemented with screws in the trochanteric region or with unicortical locked screws in the region of the stem [11]. A biomechanical comparison study revealed that methods utilizing proximal cable fixation without cortical apposition provided significantly less axial stability compared with methods in which cables and locked or unlocked screws were used [12]. However, there is a lack of clinical studies comparing these different fixation methods.

The purpose of this study was to assess the surgical outcomes and effectiveness of the cable-plate-cable technique, in which proximal fixation is achieved utilizing a dynamic compression plate (DCP) and cable loops, in Vancouver types B1 and C periprosthetic femoral fractures around hip prostheses. We hypothesized that with the prerequisites of anatomic reduction and supervised rehabilitation, patients undergoing DCP and cable fixation proximally can achieve good clinical outcomes. Therefore, we compared the clinical and radiological outcomes between proximal fixation using cable plus screws with DCP and proximal fixation using cable alone with DCP in patients with periprosthetic femoral fractures.

Materials and methods

This retrospective study conducted in a single medical center was approved by the Institutional Review Board. Data was collected from all adult patients who received ORIF for Vancouver type B1 or C periprosthetic femoral fracture between January 2010 and December 2016 with a minimum follow-up of 12 months. Included patients had a Vancouver type B1 or C periprosthetic femoral fracture treated with open reduction and fixation using Dall-Miles cable (Stryker, H'erouville-Saint-Clair, France) and DCP (DePuy Synthes, Oberdorf, Switzerland). Patients were excluded for presence of (1) multiple fractures, (2) polytrauma, (3) bed confinement status, (4) neuromuscular disorder, (5) pathological fracture, or (6) history of psychological disorder. All periprosthetic fractures were graded using Vancouver classification upon evaluation of preoperative radiographs of standard anteroposterior and lateral views of the injured hip and femur. In our institution, periprosthetic fractures were treated by two senior orthopedic surgeons who use different fixation methods. The two senior surgeons take turn to take consults for periprosthetic fractures, with each surgeon in charge for half of the month. The patient allocation was determined by day of admission and surgery was performed by the surgeon on duty. Included patients were divided into two groups according to method of fixation construction and thus the surgeon performing the procedure. Patients in Group I underwent fixation of the proximal fragment of periprosthetic fracture using DCP combined with cables and screws. Patients in Group II underwent fixation using a cable-plate-cable technique in which the proximal fragment was fixed using DCP and cables alone.

Preparation

The direct lateral approach was used with the patient in the lateral decubitus position on a radiolucent operating table. Fluoroscopy was performed throughout the procedure. Standard surgical preparation and draping were carefully executed to allow access to the limb from the top of the ilium to the mid-part of the calf. The affected extremity was draped free and a tourniquet was not used.

Stem stability

It's difficult to confirm prosthesis stability on pre-operative X-ray alone. If the stem is likely stable, the hip arthrotomy for stability testing can be avoided. Whenever possible, indirect methods for testing intraoperative stability without the need for exposing the joint should be employed. Depending on the fracture pattern and exposure, the distal implant can be tested for translation relative to the femur by means of longitudinal traction and rotation. If this is not possible, fluoroscopy can be utilized for dynamic testing in the operating room. We regarded that surgical dislocation should be performed for all cases in which the stability of the implant remains in question.

Exposure

A straight lateral thigh incision was made to expose the lateral aspect of the femur. The tensor fascia lata was incised parallel to its fibers, exposing the vastus lateralis. The vastus lateralis muscle was carefully elevated from the linea aspera posteriorly and retracted anteriorly. After identification of the fracture site, exposure was extended as needed to allow application and securing of a plate proximal and distal to the fracture. Periosteal stripping was kept to a minimum to preserve blood supply and the linea aspera was preserved of its soft-tissue attachments. If necessary, the site of the fracture was opened to remove cement debris or bone fragments.

Group I

The DCP was placed provisionally on the lateral femoral shaft with reduction clamps after adequate reduction was achieved. Whether to use cables to loop fracture site was determined by the surgeon's judgement. Alignment was then evaluated on intraoperative fluoroscopy. The fracture was fixed using only a lateral DCP of sufficient length to span the intramedullary implant as much as possible proximally and to extend beyond the fracture site by six screw holes distally. One or two cable loops were employed and at least one unicortical or bicortical screw was used to achieve rotational stability in the proximal fragment. Afterward, two or more bicortical screws with or without cable loop were used in the distal fragment (Fig. 1).

Groups II (cable-plate-cable technique)

The fracture was reduced with gentle traction force and held by reduction clamps. Then, one or two cable loops, according to the length of fracture line, were placed at the fracture site to maintain reduction (Fig. 2A and B), and the DCP was placed over the lateral aspect of the femur on top of the initial cables, which were left under the plate after fixation of the plate to the proximal and distal fracture fragments. The length of the plate was sufficient to span the intramedullary implant as much as possible proximally and to extend beyond the fracture site by six screw holes distally. The most distal screw was then inserted into the plate (Fig. 2C). The reduction alignment and plate position were evaluated using intraoperative fluoroscopy. At least two loops of cable were applied on the DCP without the use of screws at the proximal femoral fragment. Following tightening of the cable loops, the distal-most screw was tightened and the remaining distal screws were then inserted (Fig. 2D). For rigid fixation, distal screws were required to purchase at least two cortical screws with or without cable loops at the distal fragment. Distal cable loops were used for controlling plate position, and resisting pull-off stresses on the plate by opposing the tension force on lateral femur.

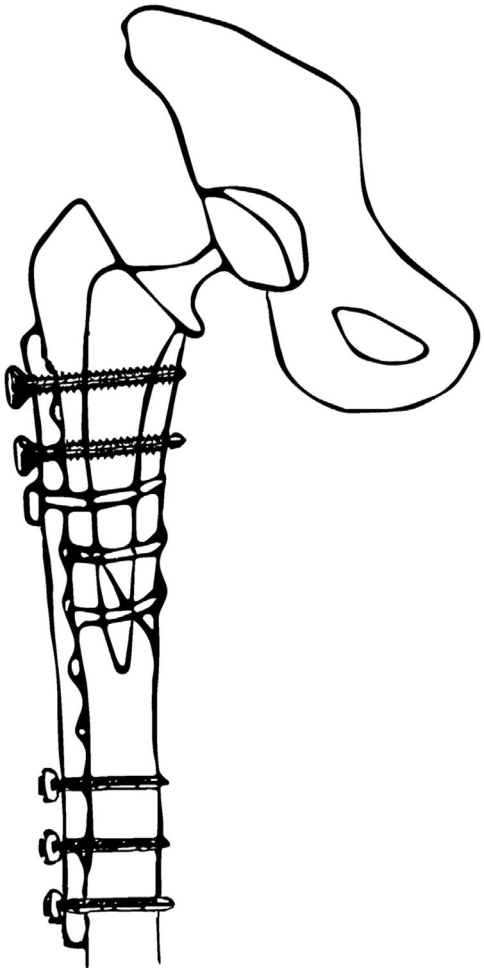

Fig. 1. In group I, the plate was placed over lateral aspect of the femur and screws plus cable loop were used to achieve stability in the proximal fragment. Bicortical screws with or without cable loop were used in the distal fragment.

Post-operative training protocol

Patients were recommended to remain non-weight bearing on the affected limb for the first month after surgery in both groups. Toe-touch weight bearing was allowed during the second post-operative month. Gradually, progressive weight bearing was allowed in accordance with radiographic evidence of callus formation or bridging trabeculae starting in the third post-operative month. Patients in both groups began flexion and extension exercises as well as isometric strengthening exercises of the quadriceps and hamstrings immediately after surgery. All patients were followed post-operatively at two weeks, six weeks, three months, six months, one year, and annually thereafter.

For both groups, patients' characteristics and surgical outcomes were reviewed by two other orthopedic surgeons who were not involved in the operative procedures. Fracture union was defined when the patient was able to fully bear weight without pain clinically and radiographic evidence of bridging callus or trabeculae across the fracture site was present. Numbers of screws and cable loops utilized were recorded through evaluation of post-operative radiographs. Functional outcome was evaluated using the Harris hip score (HHS). Pre-injury HHS was recalled by the patient and recorded after surgery during admission. Post-operative HHS was evaluated at regular follow-up visits and the latest score assessed by the two independent evaluators was used for analyzing post-operative functional outcome. Complications, including wound infection, loss of reduction, hardware failure, subsidence of stem, and non-union, were identified by review of medical charts and radiographs. All data collected in the study were recorded and analyzed using SPSS (version 22, SPSS, Chicago, IL, USA). Statistical analysis was performed using a student *t*-test for continuous variables and chi-square or Fisher's exact-test for categorical variables. A P-value less than 0.05 was considered statistically significant.

Results

A total of 68 patients with a Vancouver type B1 or C periprosthetic femoral fracture who underwent ORIF using DCP and cables were identified. Eighteen patients were excluded due to loss of follow-up (n = 10), death (n = 3), multiple fractures (n = 3), bed confinement status (n = 1), and psychological disorder (n = 1). Finally, 50 patients with a mean age of 77.4 years and mean follow-up time of 30.8 months were included, among whom 35 had a type B1 fracture and 15 had a type C fracture. Twenty-three patients were included in Group I, and 27 patients who underwent a cable-plate-cable procedure were included in Group II (Fig. 3).

In terms of demographics, there was no significant difference between groups in age, gender, Vancouver type, implant type, and length of follow-up. There was no significant difference in distal

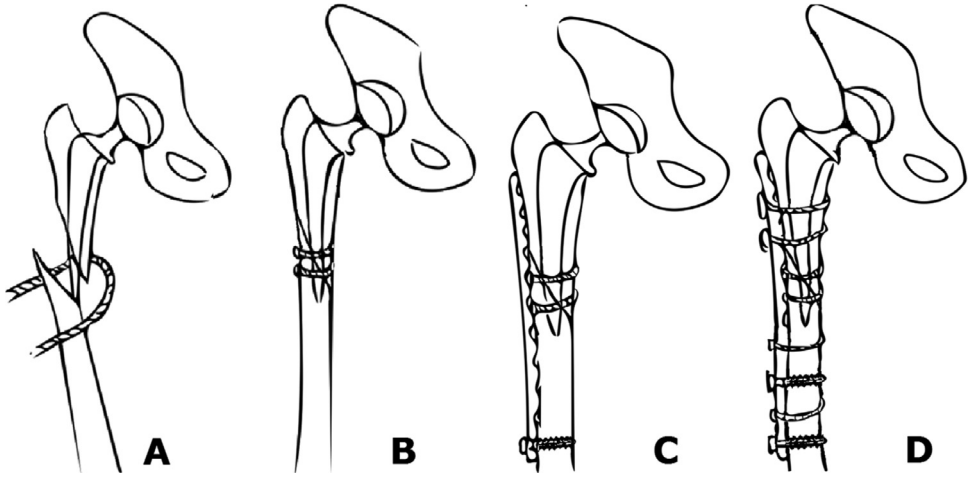

Fig. 2. In group II, the fracture was reduced with gentle traction force and held by reduction. Then, one or two cable loops were placed at the fracture site for maintaining appropriate reduction (A) (B). The plate was placed over the lateral aspect of the femur above the initial cables and the most distal screw was then inserted on the plate (C). At least two loops of cable were applied on the DCP in the proximal femoral fragment with distal screws purchasing at least two cortex screws with or without cable loops (D).

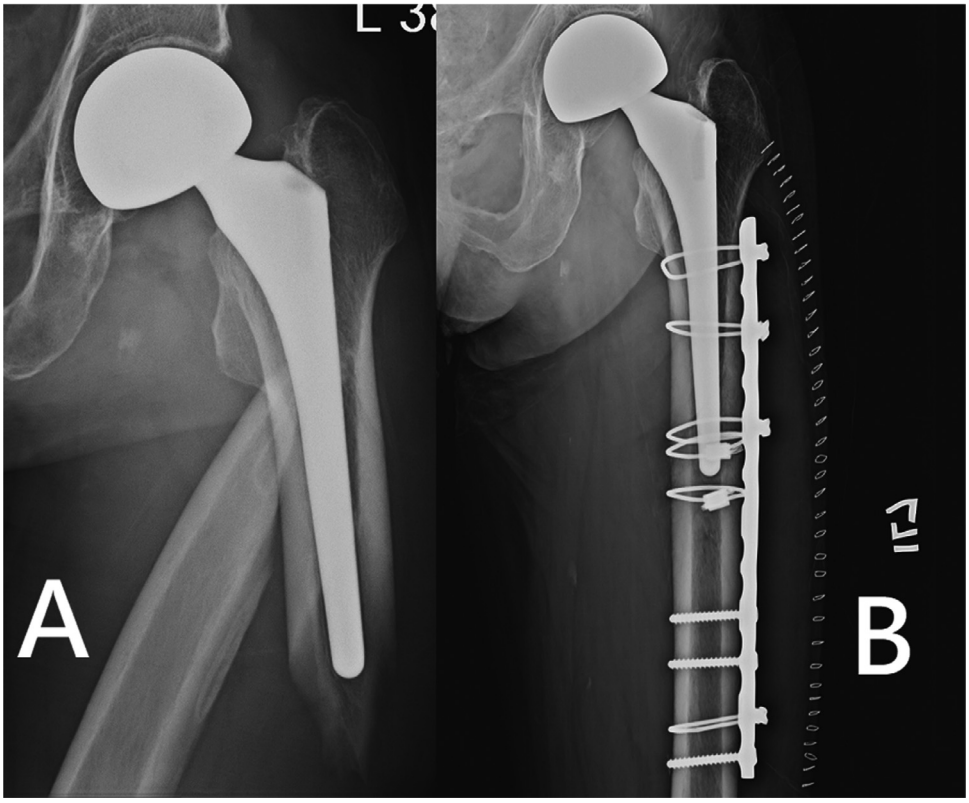

Fig. 3. A Vancouver type B1 fracture about the tip of a well-fixed stable stem (A) treated with a plate protecting adequate length of the femur using the cable-plate-cable technique in Group II (B).

constructs of screws or loops between groups. No proximal screws were used in Group II patients, however, compared with Group I patients, more cable loops were used over fracture site for maintaining reduction ($P < 0.001$). Fracture union was achieved in 49 cases; one case in Group I experienced loss of reduction and did not achieve fracture union. Mean time to union was 5.4 months in Group I and 5.1 months in Group II ($P = 0.624$). Mean pre-injury HHS was 76.1 in Group I and 75.6 in Group II ($P = 0.611$). Mean latest HHS was 69.5 in Group I and 69.4 in Group II ($P = 0.919$). No significant difference in clinical and radiological outcomes between groups was observed (Table 1).

Four complications occurred in the included patients: one stem subsidence, one septic non-union, and one loss of reduction occurred in Group I; one stem subsidence was observed in Group II (Table 2).

One patient with a Vancouver type B1 fracture in Group I experienced stem subsidence during the third month after fixation. Initial management of this patient consisted of conservative treatment by having the patient remain non-weight bearing. However, symptoms of limping and hip pain persisted, and the patient was willing to undergo revision surgery during the tenth post-operative month. Due to near complete healing over the femoral fracture site, revision to a long femoral stem without revision of fracture fixation was performed. The patient experiencing infection in Group I presented with wound discharge during the first post-operative month, and was successfully treated with debridement and antibiotics. Bony union was achieved in this patient seven months after the initial fracture fixation. Also in Group I, one patient suffered from loss of reduction in the fifth post-operative month, but the patient declined revision surgery. Protected partial-weight bearing was recommended until evidence of radiologic bony healing was observed. After ten months of protected non-weight bearing, bony union was achieved with malalignment. In Group II, one patient experienced subsidence of the bipolar stem during the third month, and she underwent revision surgery of the long femoral stem one year post-operatively.

Table 1
Patients characteristics.

	Group I (n = 23)	Group II (n = 27)	P value
Age (year)	76.4 ± 9.6	78.4 ± 14.1	0.564
Gender	10	13	0.741
Male	13	14	
Female			
BMI	22.3 ± 3.8	21.9 ± 3.1	0.701
Side			0.945
Right	13	15	
Left	10	12	
Implant			0.662
Bipolar	10	9	
Cement Austin Moore	4	8	
THR	4	6	
Revision THR	5	4	
Vancouver type	16	19	0.951
B1	7	8	
C			
Fracture site loops	0.69 ± 0.76	1.41 ± 0.51	<0.001
Proximal screws	2.88 ± 1.41	0	<0.001
Proximal loops on plate	2.65 ± 1.15	3.07 ± 0.83	0.139
Distal screws	3.74 ± 0.92	3.25 ± 0.90	0.069
Distal loops on plate	1.09 ± 0.67	1.48 ± 0.81	0.068
OP time (min)	131.3 ± 43.8	129.2 ± 29.5	0.845
Duration to union (month)	5.39 ± 1.75	5.14 ± 1.72	0.624
Follow up time (month)	27.2 ± 14.1	33.8 ± 18.8	0.169
Pre-injury HHS	76.1 ± 3.7	75.6 ± 3.8	0.611
Latest HHS	69.5 ± 3.7	69.4 ± 4.2	0.919

Abbreviation: Body Mass Index (BMI), total hip replacement (THR), Harris hip score (HHS): Continuous variables mean ± standard deviation.

Table 2
Complications.

	Group I (n = 23)	Group II (n = 27)	P value
			0.459
Stem subsidence	1	1	
Infection	1	0	
Loss of reduction	1	0	

Discussion

In this study, we assessed the clinical and radiological outcomes following osteosynthesis using a cable-plate-cable technique for Vancouver types B1 and C periprosthetic fractures. All patients who underwent surgery utilizing this technique (Group II) achieved bony-union of the femoral fracture site and acceptable HHS at the latest clinic follow up. Union rate and clinical outcomes in Group II patients were comparable to those of patients in Group I in whom proximal fragment was fixed with screws and cable. Results of our study suggest that proximal screws may not be necessary for the fixation of the proximal fragment of a periprosthetic fracture under the prerequisite of appropriate reduction, sufficient cable fixation, and supervised rehabilitation.

Achieving adequate fixation in the proximal fragment of a periprosthetic fracture around the hip stem is a challenge for orthopedic surgeons. Several techniques have been described for fixation of Vancouver types B1 and C femoral shaft fractures after hip arthroplasty. Biomechanical studies have evaluated various periprosthetic femoral shaft fracture fixation techniques in order to determine load to failure and mode of failure [12–14]. Simon et al. [14] reported that fixation of the proximal fragment with cable alone on the plate was less rigid than fixation with locking screws on the plate. Furthermore, increasing the fracture gap considerably reduced the stiffness of the construct in all methods of fixation. Harry et al. [12] evaluated four different constructs on the plate proximally using unicortical locking screws, unicortical locking screws with cables, unicortical standard screws with cables, or cables alone. The authors concluded that cables alone were the least resistant to failure compared with the other three fixation constructs, and that fixation using a combination of locked or non-locked screws and supplemental cable is recommended. Moreover, in that study, the cables were typically on top of plates supplemented with screws in the trochanteric region or with unicortical locked screws in the zone of the stem. However, there has been no clinical study evaluating the outcome of proximal fragment fixation using cable and plate alone. Results of our study show that the cable-plate-cable technique provided good clinical outcome without occurrence of non-union.

Although the use of proximal screws around the stem are regarded as an important construct for rotational stability [15,16], drilling with appropriate direction into the cortex for purchasing screws in rigid screw fixation is not possible for every fracture. Obtain enough bone purchase was also difficult particularly in osteopenic bone. In contrast to the techniques used in the previously mentioned biomechanical studies, our technique utilized cables to rigidly compress the fracture line followed by application of the plate above the reduction cables over the proximal fragment. Compared to patients in Group I, more cable loops were used for fracture site reduction in Group II patients due to surgeon's preference. The importance of the cable loops for maintaining rotational stability must be emphasized; in Group II, the cables underneath the cable plate were locked at the fracture site and tightly maintained the reduction. In this study, the cable-plate-cable technique without use of additional proximal screws provided similar clinical and radiological outcomes compared to the conventional surgical technique of DCP with proximal screws and cable loops. We thought that insertion of screws around a well-fixed stem can be technique demanding and time consuming, however, screws may be not necessary to obtain adequate stability in osteopenic periprosthetic femoral fracture.

The main advantage of proximal fragment fixation with cables alone without proximal screws is to preserve femoral canal for future revision surgeries, such as exchange stem for femoral stem loosening or conversion to total hip replacement. Revision to larger long stem is a common option, and removal of all proximal screws for reaming and better stem-bone contact seemed to be inevitable. And, extending the surgical wound in order to remove the proximal screws is not necessary to the cases with cable-plate-cable technique. In addition, poor bone stock of proximal femoral is usually found in these cases, therefore, cable loops with plate in the proximal femur could protect the reaming and press-fitting process at revision arthroplasty. If the selected revision stem is likely to impinge on a distal screw, the distal screw may be removed percutaneously. In published studies, some hemiarthroplasties fail and they should be revised for complex of impaired walking, groin pain, or leg length discrepancy. Reoperation rate has been reported between 5% and 24% in patients with hemiarthroplasty failure [17]. Therefore, revision surgery for hemiarthroplasty was not rare, we regarded that easier revision of stem was important issue for some patients who had history of periprosthetic fracture.

Studies have suggested that stabilization requires three or more equally spaced cables placed proximally between the lesser trochanter and the tip of the stem with at least 6 holes covering the intact femur distal to the fracture [11,14,18]. In our study, an average of 3.09 loops were used on the plate for proximal fixation with additional fracture site loops, and an average of 3.3 bicortical screws were used for distal fixation. Despite the increased popularity of locking screws in recent years, non-locking screws were used for fixation in this study due to limitations of health insurance reimbursement. In an osteoporotic cadaveric bone study [12], constructs with locking and non-locking screws demonstrated equivalent loads at failure. An extensive systematic review [19] comparing non-locking and locking plates in Vancouver B1 or C periprosthetic femoral fractures revealed that union rate and time to union were unaffected by plate type. These findings suggest that non-locking screws are sufficient for rigid fixation of the distal fragment in Vancouver types B1 and C periprosthetic femoral fractures.

Stem loosening after osteosynthesis for periprosthetic femoral fracture could be related to inattention to initial stem instability; therefore, thorough history taking and careful observation of pre-fracture and post-fracture radiographs are suggested [11,20]. Stability of the stem is commonly evaluated and confirmed intraoperatively, and in our cable-plate-cable technique, stability of the stem was intraoperatively confirmed through assessment of longitudinal traction and rotational torque and inspection of the cement-bone, implant-cement, and implant-bone interface. If the stability of the implant remains in question, hip arthrotomy will be performed. Despite intraoperative evaluation, two cases in our study experienced stem subsidence complications after osteosynthesis, which may have resulted from occult instability. To improve prevention of this complication, hip arthrotomy in all cases to confirm stem stability has been advocated by some studies [11,21]. Due to the complexity of these injuries, we suggest that surgeons must have the adequate reconstruction skills, thorough pre-operative planning, and resources for revision arthroplasty if intra-operative unstable femoral stems are found.

There are some limitations to this study. First, the number of patients was limited. Further study with a larger number of patients would provide stronger evidence. Second, owing to the retrospective design, possible confounding and bias may have influenced the accuracy of the clinical parameter estimates. The review-

ers who performed the radiographic and surgical outcome measurements, however, did not participate in the surgeries, limiting reviewers' bias. Third, cable-plate-cable technique was not suitable to more complex or transverse type fracture, because it's difficult to loop fracture site by cable. However, no complex or transverse type fracture was found in the enrolling period. Actually, only a small percentage of post-operative stable stem periprosthetic fractures were comminuted or transverse type in a total 32,644 patients study [22]. Therefore, the cable-plate-cable technique is still an ideal technique for most of post-operative periprosthetic fracture. Fourth, the surgeon of group I didn't routinely use the cable over fracture site. Therefore, the amount of cable loops over fracture site was significant different between two groups and differences in outcome may be mitigated by this variable. Finally, assessment of clinical outcome required pre-injury HHS obtained from patient recall, which may have been inaccurate.

Conclusions

With the prerequisite of ideal reduction and supervised rehabilitation, the cable-plate-cable technique is a reliable procedure for the treatment of Vancouver types B1 and C periprosthetic femoral fractures and provides good surgical outcomes.

Conflict of interest

Tzu-Cheng Yang, Yun-Hsuan Tzeng, Chien-Shun Wang, Chun-Cheng Lin, Ming-Chau Chang and Chao-Ching Chiang declare that they have no conflict of interest

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