The purpose of this study was to evaluate the efficacy and safety of the proximal femoral locking plate with cannulated screws for the treatment of femoral neck fractures. A prospective study was performed in 41 patients with femoral neck fractures treated with a proximal femoral locking plate with cannulated screws between January 2005 and December 2008. Twenty-five men and 16 women had a mean age of 47 years (range, 21-65 years). The time from injury to surgery ranged from 2 hours to 7 days. Three patients had a Garden type I fracture, 9 a type II, 18 a type III and 11 a type IV. Operative time, intraoperative blood loss, fracture healing time, Harris Hip Score for hip function, and complications were recorded to evaluate treatment effects.

Mean operative time was 63.6 minutes (range, 40-90 minutes), with mean intraoperative blood loss of 84.2 mL (range, 50-200 mL). Mean time to union was 15.5 weeks (range, 12-36 weeks). Two patients (Garden type III and type IV) did not achieve union, and 4 patients (1 Garden type III and 3 type IV) had avascular necrosis of the femoral head. In patients with nonunion, 1 (Garden type III) underwent intertrochanteric osteotomy, and the other underwent total hip replacement (THR). In patients with avascular necrosis, 2 required THR and the others (1 Garden type III) required no further surgery. Twenty-six (63%) patients had excellent results, 8 (20%) had good results, 3 (7%) had moderate results, and 4 (10%) had poor results. These findings suggest that the proximal femoral locking plate with cannulated screws for the treatment of femoral neck fractures is effective and results in fewer complications, especially for Garden type I, II, and III fractures.
Hip fractures are common and comprise approximately 20% of the operative workload of an orthopedic trauma unit.\(^1\) Femoral neck fractures account for approximately 50% of all hip fractures.\(^1\) Life expectancy is increasing worldwide, and these demographic changes can be expected to cause the number of hip fractures occurring worldwide to increase from 1.66 million in 1990 to 6.26 million in 2050.\(^1\) The estimated annual cost of treating these fractures is enormous and a significant burden on any health care system.\(^1\)

The treatment of femoral neck fractures remains controversial. Although various techniques have been developed for internal fixation with open or closed reduction of femoral neck fractures, non-union and femoral head avascular necrosis are major complications that require numerous solutions.\(^2\)-\(^6\) Therefore, carefully selecting the correct operation to provide the best outcome while avoiding the need for a second operation is the gold standard of care.\(^7\) In this study, we used a proximal femoral locking plate with cannulated screws designed by our department to evaluate its efficacy and safety in femoral neck fracture fixation.

**MATERIALS AND METHODS**

Between January 2005 and December 2008, forty-one patients with femoral neck fractures were treated with a proximal femoral locking plate with cannulated screws. Patients with pathologic fractures, autoimmune diseases, blood disorders, severe multiple trauma, and surgical contraindications were excluded. Anteroposterior (AP) and lateral radiographs of the hip joint were taken in all patients, and computed tomography (CT) scans were obtained if necessary.

Twenty-five men and 16 women had a mean age of 47 years (mean, 21-65 years). Twenty-seven patients had a right-side fracture and 14 patients had a left-side fracture. The reasons for injury included motor vehicle accident (n=18), fall from a height (n=14), simple fall (n=7), and sports activities (n=2). The time from injury to surgery ranged from 2 hours to 7 days. Twelve patients had a delay in fracture fixation of 24 hours. Seven patients had undisplaced femoral neck fractures and 5 had displaced. Garden classification was used for fracture classification (types I and II, undisplaced; types III and IV, displaced).\(^8\) Three patients had type I fractures, 9 had type II, 18 had type III, and 11 had type IV.

The proximal femoral locking plate used in this study (Double Engine Medical Material Co Ltd, Xiamen, China) was designed to configure the proximal femur. Therefore, the good fit of the plate and its bone surface had been proven intraoperatively. The cannulated screws were shaped like locking screws, with a diameter of 7.3 mm (Figure 1).

**SURGICAL TECHNIQUE**

All patients underwent surgery under spinal anesthesia or general anesthetic. After careful positioning of the patient on the fracture table, the hip was exposed through an anterolateral approach (Watson-Jones) in the supine position,\(^9\) and a longitudinal capsular incision was made to the anterior aspect of the fracture. After evacuation was completed under direct vision, the capsular incision was not closed. Anatomical reduction was confirmed by fluoroscopy before internal fixation. A 3.0-mm guidewire was inserted along the inferior portion of the femoral neck, parallel to the axis of the neck, into the subchondral bone of the head. Care was taken to ensure that this guidewire was placed centrally in the neck on the lateral view. After satisfactory insertion of the guidewire, fixation was achieved with the proximal femoral locking plate.

Patients with no other problems were discharged 1 week postoperatively and returned for follow-up at 6 weeks, 3 and 6 months, and 1 and 2 years postoperatively. Patients were rapidly mobilized and instructed to use toe-touch weight bearing with crutches or a walker for 12 weeks. Patients progressed to full weight bearing when they had the strength and balance to do so. They were instructed to wean off of crutch support when they were able to walk without a substantial limp.

In clinical evaluation at latest follow-up, pain, limitation of movement, and shortness were noted. On radiological evaluation, degree of the union, loss of fracture alignment, trabecular integrity at the fracture line, late segmental collapse, and the presence of avascular necrosis were observed. Avascular necrosis was assessed according to the criteria of Ficat.\(^10\) Patients were evaluated by the Harris Hip Score for hip function.\(^11\) The mean follow-up period was 43 months (range, 24-69 months).

**RESULTS**

No intraoperative complications occurred. Mean operative time was 63.6 minutes (range, 40-90 minutes), with a mean intraoperative blood loss volume of 84.2 mL (range, 50-200 mL). Radiography of all patients showed that the positioning of the internal devices was good, and the screws did not pull out of the articular surface of the femoral head. Postoperative radiographs were evaluated.
for the quality of femoral neck reduction as described by Haidukewych et al. Fracture reduction was classified as excellent (<2 mm of displacement and <5° of angulation in any plane), good (2-5 mm of displacement or 5°-10° of angulation), fair (>5-10 mm of displacement or >10°-20° of angulation), or poor (>10 mm of displacement or >20° of angulation or any varus). Device placement was excellent in 29 patients, good in 9, and fair in 3.

Mean time to union was 15.5 weeks (range, 12-36 weeks). Patients with Garden type I and II fractures achieved union in 3 months. Two patients experienced nonunion (1 Garden type III and 1 type IV). These patients had a delay in fracture fixation of 48 hours due to transfer from other hospitals. Femoral head avascular necrosis developed in 4 patients (1 Garden type III and 3 type IV). The time from injury to surgery varied from 8 hours to 7 days. One patient with Garden type III nonunion underwent intertrochanteric osteotomy in the 18th postoperative month, and the other (Garden type IV) underwent total hip replacement (THR) in the 24th postoperative month. These patients were considered poor outcomes. In patients with avascular necrosis, 2 (Garden type IV) required THR and were considered poor outcomes. The other patients (1 Garden type III and 1 type IV) required no further surgery and were considered moderate outcomes.

According to the Harris Hip Score, 26 (63%) patients had excellent results, 8 (20%) had good results, 3 (7%) had moderate results, and 4 (10%) had poor results (Table 1). A typical case is shown in Figure 2.

### DISCUSSION

Controversy exists regarding the methods of femoral neck fracture fixation. Nonoperative treatment is an option in undisplaced femoral neck fractures; however, studies show that a significant risk of displacement exists during nonoperative treatment. Therefore, the majority of undisplaced femoral neck fractures are treated with internal fixation. In contrast with undisplaced fractures, for which there is general agreement regarding treatment, considerable variation exists in the treatment of displaced femoral neck fractures. For the majority of elderly patients with displaced femoral neck fractures, THR is the best choice. A displaced femoral neck fracture in a young patient requires more urgent treatment. These fractures should be treated by reduction and fixation immediately. Treatment should not cause injury to the residual blood supply to the femoral head and neck. In modern orthopedic practice, the usual choice is either a sliding hip screw device or a cannulated screw system. These have superseded older devices such as hook pins, Knowles pins, and the Watson-Jones nail, but these implants were documented as having results comparable with more modern implants.

Several studies have compared sliding hip screw devices with cannulated screw implants for these fractures. Two meta-

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Figure 2: Preoperative anteroposterior (A) and lateral (B) radiographs, day of surgery anteroposterior (C) and lateral (D) radiographs, and 12-week postoperative anteroposterior (E) and lateral (F) radiographs of a 43-year-old man with a left femoral neck fracture.
analyses have addressed the issue of implant selection, analyzing >25 trials comparing implants. These meta-analyses concluded that no clear evidence of superiority of any 1 implant existed for fixation of these fractures. Cannulated screw systems have the advantage of a less invasive surgical exposure with less blood loss and pain and are the most popular choice. However, most surgeons emphasize the importance of buttress fixation on the inferior-medial cortex when using cannulated screw systems. The calcar is a region of the femoral neck that extends caudal and lateral from the inferior femoral neck toward the lateral cortex. The rationale for an inferior screw close to the calcar is that the inferior cortex can act as a buttress for an adjacent screw if good screw purchase in the femoral head is obtained. Aminian et al reported that the 3-cannulated-screw configuration is the weakest construct for stabilizing a vertical shear femoral neck fracture, followed in ascending order by the sliding hip screw and proximal femoral locking plate. Therefore, nonunion and femoral head avascular necrosis are common complications of femoral neck fracture fixation with cannulated screw systems. These complications are primarily mechanical, caused by the failure of the cannulated screw to hold the fracture stable enough while it heals.

Our original goals in designing the proximal femoral locking plate with cannulated screws were to fix the fracture with a minimally invasive technique, avoid iatrogenic injury to the blood supply to the femoral head and neck, and strengthen biomechanical stability with the bolt-plate locking design. Three cannulated screws are fixed together to guarantee stability, reduce the position placement requirement of screws, and avoid loosening and withdrawal of cannulated screws.

We combined the proximal femoral locking plate with the cannulated screws. The instrument is simple, short, and designed to configure to the proximal femur. A small incision is convenient for placement and fixation. Therefore, compared with the sliding hip screw device, the proximal femoral locking plate also has the advantage of a less invasive surgical exposure with less blood loss. Meanwhile, cannulated screws are designed to lock the nail head and strengthen biomechanical stability. The overall rate of nonunion for patients in this series was 5%. When split into fracture type, no undisplaced fractures and 7% of displaced fractures experienced nonunion. This compares favorably with other implants (Table 2).

Regarding avascular necrosis, the overall rate in this series was 0 for undisplaced fractures and 14% for the displaced fractures, which is again lower than with other implants. Meanwhile, the reoperation rate in this series was 0 for the undisplaced fractures and 14% for the displaced fractures, which is again lower than the case of other implants reflected in Table 2.

The timing of surgery for femoral neck fractures remains controversial, and the available data remain inconclusive.
our series, 5 patients with displaced femoral neck fractures had a fixation delay of 24 hours, and 2 experienced nonunion. Seven patients with undisplaced fractures had a fixation delay of 24 hours, and none experienced nonunion or avascular necrosis. We recommend that surgery be done on an urgent basis. Open reduction and internal fixation of the displaced femoral neck fracture should be performed as soon as the patient is considered stable. An urgent operation allows early reduction, capsular decompression, restoration of the anatomy, and restoration of femoral head vascularity by uninking the vessels. However, no marked correlation exists between the timing of surgery and undisplaced femoral neck fractures.

This study has limitations. Whether the proximal femoral locking plate is correctly positioned determines the position of the cannulated screws to avoid their placement into the joint. Therefore, the placement of the proximal femoral locking plate should be preformed with the help of C-arm radiography to assure precise positioning. Furthermore, the effect of locking fixation is inferior to that of nonlocked cannulated screws on femoral neck fractures. Therefore, a nonlocked cannulated screw should be used first for fixation after confirming the effect of fracture reposition and then fixed with locking cannulated screws.

REFERENCES


