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Given the encouraging results of biomechanical studies on femoral neck fractures, are locking plates more safe?

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This current study compares the clinical and radiological outcomes of femoral neck fractures in young adults treated with either cannulated screws (CS) or proximal femoral locking plates (PFLP).

We conducted a retrospective study in patients aged 18 to 60 years with femoral neck fractures and investigated medical records between January 2005 and December 2016. Patients were divided into two groups based on implants, screw and plate, used for fixation assigned. In addition, two groups were compared for their complications and functional outcomes, which were assessed with Harris Hip Score (HHS) and Parker Palmer mobility scores.

Sixty-nine of 104 patients met the inclusion criteria. Forty patients were treated with cannulated screws, while 29 were treated with a proximal femoral locking plate. The two groups were comparable in terms of their perioperative variables. The overall complication rate (screw group, n = 10; plate group, n = 14) and non-union rate were significantly high in the plate group ($p < 0.05$). Other complications did not show statistically significant differences. The screw group had better functional outcomes than the plate group, where only the Parker-Palmer mobility score comparison was significant ($p < 0.05$). Poor reduction quality and Pauwels' type III fractures were statistically associated with high complication rates regardless of the implants used ($p < 0.05$).

Although PFLP showed better outcomes in biomechanical studies than CSs, we observed poorer clinical results. Therefore, although some of our results appeared to be statistically significant, reduction quality should also be considered.

Keywords: Femoral neck fractures, cannulated screws, proximal femoral locking plate, complications, non-union, avascular necrosis.

INTRODUCTION

In young patients under 60 years, femoral neck fractures develop through high-energy mechanisms[1]. Their high complication rates (e.g., femoral neck shortening, non-union, osteonecrosis) and negative impact on functional outcomes due to alteration in hip biomechanics pose a challenge for both the patient and the orthopedic surgeon[2,3]. Therefore, treatment's primary goal is to preserve the femoral head through precise reduction and stable osteosynthesis[4]. Arthroplasty remains a treatment of choice, primarily in the elderly. Although the need for anatomic reduction continues to be accepted, the optimal fixation method remains controversial[5]. Cannulated screws (CS) and sliding hip screws are widely preferred options in managing femoral neck fractures. They have been investigated and compared in many studies[2,6,7]. Anatomical proximal femoral locking plates (PFLP) offer stable fixation for proximal femoral fractures with multiple screwing and locking options[8]. Although some biomechanical studies examine the above implants, the studies are insufficient to evaluate actual clinical outcomes of PFLPs[9]

We mainly used CSs and PFLPs as implants in treating proximal femoral fractures. We compared the CS and PFLP in terms of 1) union rate, 2) revision surgery, 3) functional score and mobility.

PATIENTS AND METHODS

After approval by the institutional ethics committee, we retrospectively reviewed the medical records of patients admitted to our hospital with a femoral neck fracture between January 2005 and December 2016 and surgically treated with either CSs or PFLP. Patients younger than 18 and older than 60 years, with pathologic fractures, open fractures, fractures extending to the trochanteric region or beyond, previous

history of femoral fractures, polytraumatized patients, patients with severe comorbidities (American Society of Anesthesiologists [ASA] Score Grade V) and with a follow-up period less than one year were excluded. There were 104 patients with a femoral neck fracture, 69 of whom met the inclusion criteria. They were divided into the screw group (n = 40 patients) and the plate group (n = 29 patients), representing patients treated with CSs and PFLP, respectively.

Surgical procedure

All patients were systematically examined after admission to our emergency department. Fracture fixation was performed as soon as possible. Patients received a single dose of cefazolin prior to surgery and were placed supine on a radiolucent table. The surgeries were performed under general or regional anesthesia, depending on the anesthesiologist's preference. Closed reduction was achieved by manual traction and manipulation under fluoroscopic guidance. Pauwels' classification[10] was used to classify fractures, where the angle of fracture inclination is < 30° for Type I, 30°-50° for type II, and > 50° for type III. According to suggestions by Turgut et al.[11], fracture classifications were performed using intraoperative fluoroscopic images after reduction. The reduction quality is determined intraoperatively using the Haidukewych criteria[12] (Table I). Anatomical reduction or slight valgus was the aim of reduction maneuvers. If we did not achieve an acceptable closed reduction, we proceeded with open reduction via the Hueter approach. A lateral longitudinal incision was performed above the lesser trochanter in the screw group. Three or four partially threaded 6.5mm cannulated screws were inserted freehand over the guide wires. The configuration of screws and thread length were determined according to the type and characteristics of the fracture. We used the Watson Jones approach in the plate group, and plating was performed according to the manufacturer-recommended technique. Anteroposterior (AP) and frog-leg views of the hip were evaluated under fluoroscopy after the surgery.

Table I. — Assessment of reduction quality according to Haidukewych criteria

Quality of reduction	Amount of displacement	Residual angulation
Excellent	< 2mm	and <5°
Good	2-5mm	and / or 5°-10°
Fair	5-10mm	and / or 10°-20°
Poor	> 10mm	and / or > 20°

Protocol after surgery

All patients received antibiotics and deep venous thrombosis prophylaxis for 24 hours and four weeks, respectively. The same rehabilitation protocol was used in all patients. After the second day of surgery, patients were ambulated with touch-down weight bearing using two crutches. After that, in the sixth postoperative week, the patients were allowed to increase their weight-bearing status gradually. Finally, in the second month, they started with unrestricted weight-bearing.

Patients were called for follow-up visits at the sixth postoperative week, the third month, the sixth month, the first year, and annually. Control pelvic AP and lateral radiographs of the operated hip were taken. In order to obtain accurate values, all X-ray images were uploaded to Probel Picture Archiving Communication System (PACS) DICOM Viewer V.2.1.10 (Probel Yazilim, Izmir, Turkey), which allows digital measurements. One of us (KG), not involved in the surgical management of the patients, evaluated all patients and the most recent radiographs. Any changes in neck-shaft angle, progression to varus collapse, avascular necrosis (AVN), implant failure, or non-union were noted. Non-union was defined as a persistent fracture line that had not healed nine months after surgery, loss of fixation associated with pain, and radiographic findings. Varus mal-union was defined as more than 10° of angulation in comparison to the uninjured hip. According to the Dindo et al.[13], complications were identified and classified from Grade I to V. Complications requiring revision surgery under general anesthesia were classified as Grade IIIb. Walking abilities at the first-year visit were evaluated using the Parker-Palmer mobility score[14]. A score of nine indicates no difficulty during mobilization, and zero indicates complete disability. The Harris Hip Score[15], scaled between zero and 100, was used for functional outcomes.

Statistical analysis

The authors did not perform a prior power analysis and consider this a pilot study. Statistical analysis was performed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Categorical variables were compared and analyzed using chi-square and Fisher exact tests. Continuous data were analyzed using the Shapiro-Wilk test to assess normality.

Normally distributed data were analyzed with a t-test. Mann-Whitney U test was performed for non-normally distributed data. The level of significance was taken as $p < 0.05$.

RESULTS

Sixty-nine hips of 69 patients were included in our study. Screw group and plate group demographics and perioperative data and p-values are presented in Table II. Apart from the mean follow-up time ($p = 0.021$), there were no significant differences between the groups with regards to the age at the time of surgery, gender, fracture site, time of fixation, Pauwels' Classification, Garden Classification, reduction quality, and Parker Palmer Mobility scores before fracture ($p > 0.05$).

Overall, complications were observed significantly more frequently in the plate group than in the screw group (screw group, n = 10; plate group, n = 14; $p = 0.045$). Avascular necrosis and varus mal-union complications did not differ significantly between the groups ($p > 0.05$). However, the non-union rate in the plate group was significantly high ($p = 0.043$). The results are summarized in Table III. We did not observe any superficial or deep infection in any group.

Although the Harris Hip scores were higher in the screw group at the latest follow-up, there was no statistically significant difference between the two

Table II. — Patients demographic and perioperative characteristics, CS: Cannulated screw; PFLP: Proximal femoral locking plate

	Screw group (CS; n = 40)	Plate group (PFLP; n = 29)	p value
Age (years)	44.3	44.2	0.715
Sex (male/female)	25/15	20/9	0.578
Side (right/left)	17/23	12/17	0.926
Follow-up time (months)	50.7	32.5	0.021
Timing of fixation			0.37
0-6 hours	9	6	
7-12 hours	10	14	
12-24 hours	9	4	
25-72 hours	6	2	
>72 hours	6	3	
Pauwels' Classification			0.654
I	9	4	
II	7	6	
III	24	19	
Garden Classification			0.608
I	4	2	
II	7	2	
III	26	22	
IV	3	3	
Quality of reduction			0.762
Excellent	13	7	
Good	21	19	
Fair	5	3	
Poor	1	0	
Preoperative Parker-Palmer score	8.9	8.8	0.35

groups (screw group: 73 ± 4.9; plate group: 60.9 ± 7.3; p = 0.122). On the other hand, the screw group had significantly better results in Parker-Palmer mobility scores at the last follow-up (screw group: 7.8 ± 0.2; plate group: 7 ± 0.3; p = 0.036).

The quality of reduction was significantly associated with the overall complication rate, with one patient (100%) with poor reduction and six patients (75%) with fair reduction having a complication (p = 0.002). Irrespective of the implants used, Pauwels' and Garden classifications proved to be significantly relevant for the overall complication rate. Pauwels' type I fractures healed without complications. Nineteen fractures (44.2%) classified as Pauwels' III resulted in complications (p = 0.006). In Pauwels' type II fractures, the two groups did not differ significantly in complications (p > 0.99). In the investigation of 43 patients with Pauwels' type III fractures, complications occurred in 12 patients in the plate group and seven patients in the screw group, which were statistically significant (p = 0.026). All but one of the non-displaced femoral neck fractures (Garden I and II) healed without complications. However, displaced fractures (Garden III and IV) were significantly associated with overall complications (p=0.013), the relevance of which was unrelated to the implant types used (p=0.271).

We found no statistically significant relevance between groups and revision rates. Eighteen patient complications required revision surgery under general anesthesia and were classified as grade IIIb complications. Eight patients in the screw group and ten in the plate group had revision surgery (p = 0.176). In the screw group, the fracture fixations of six patients (four patients with AVN, one patient with non-union, and one patient with varus mal-union) and two patients with non-union were revised with total hip arthroplasty (Fig. 1) and valgus osteotomy, respectively. Total hip arthroplasty was performed in seven patients in the plate group (two patients with AVN, five patients with non-union), and three fracture fixations resulting with non-union were revised with a valgus osteotomy (Fig. 2).

DISCUSSION

Since preserving the femoral head is a worthwhile goal in treating femur fractures in young patients, they require surgical intervention. In addition, successful

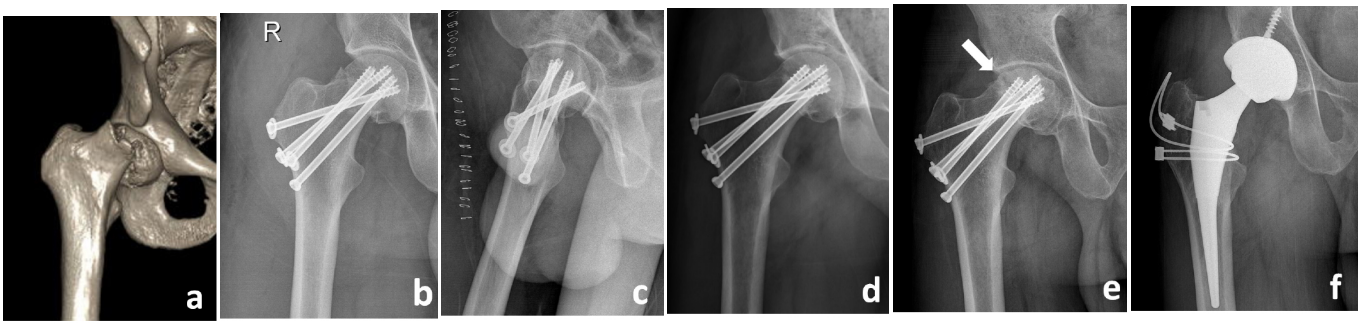

Fig. 1. — A thirty-three years old male patient with Pauwels' type III fracture a) 3-D reconstructed image shows the nature of the fracture b and c) postoperative radiographs showing fair reduction and fixation with cannulated screws d) Fracture union was achieved at the eighth postoperative month in varus position e) Necrosis of femoral head was evident after 19 months. f) Total hip arthroplasty was performed as revision surgery.

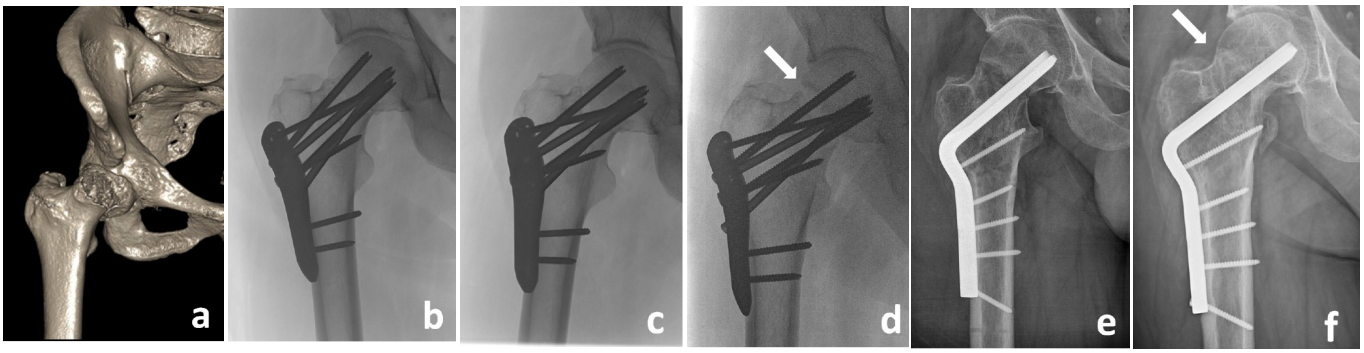

Fig. 2. — A Fifty-four years old male patient with Pauwels' type III fracture a) 3-D CT reconstruction shows the nature of the fracture b and c) postoperative radiographs d) Postoperative tenth-month control radiograph, arrow shows the persistent fracture line with bone resorption. e) Valgus osteotomy performed as revision surgery f) Complete union was achieved after revision surgery.

treatment necessitates precise reduction and stable internal fixation. Unfortunately, femoral neck fractures result in high complication rates even in non-displaced fractures due to the high energy trauma mechanism[16,17].

Cannulated screws are widely used options due to minimally invasive insertion techniques, torsional stability, and lower infection rates[16,18,19]. However, concerns about complications forced the authors to investigate and compare other fixation methods and find out possible risk factors causing them. Pauwells' type I fractures are more horizontal, resulting in compressive forces on the fracture line after reduction. Therefore, cannulated screws used for fixation are usually perpendicular to the fracture line. With increasing fracture angle, however, the shear forces predominate. Therefore, the authors tried to determine the optimal configuration of cannulated screws. Gümüştaş et al.[19] and Hawks et al.[20], after their biomechanical studies comparing three different cannulated screw configurations, suggested inserting a trochanteric lag screw into the calcar region in addition to the classic configuration of cannulated screws. So far, mainly cannulated screws and sliding hip screws have been investigated as implants. In their cadaver study, Husby et al.[21] investigated the torsional stabilities of Bahr screws and hip compression screws with side plates. They reported that three 5.5mm screw configurations were more resistant to torsional forces. Baitner et al.[22] reported similar results, noting that sliding hip screws require a higher load to failure than cannulated screws. A cadaver study conducted by Clark et al.[23] showed no significant biomechanical differences when comparing sliding screws and cannulated screws.

Locking compression plates is not an old option in managing proximal femoral fractures. Although the early biomechanical reports were based on the 1990s, Aminian et al.[24] conducted the first biomechanical studies in 2007. They stated that the PFLP had the highest stiffness and durability at higher loads, with the cannulated screws forming the weakest implant configuration. According to them, multiple screws in the head and neck area transmit the varus forces from the bone to the plate via the rigid screw-plate construct, which helps eliminate screw toggling. In 2012 Nowotarski et al.[8] reported the results of biomechanical analysis of a newly designed PFLP in Pauwels' type C fractures. In contrast to the study mentioned above, the study was conducted with synthetic bone and lower axial loads. PFLP revealed better results compared to cannulated screws. In addition, better and similar rotational stability was achieved when a transverse calcar lag screw was inserted.

Our retrospectively designed clinical study investigated the clinical and radiological outcomes of femoral neck fractures fixed with PFLPs and compared them with traditional cannulated screws. A total of 69 patients (PFLP, n = 29) with a proportion of 62.3% Pauwels' type III fracture were included in our study. Furthermore, the mean age was 44.2 years. The two groups were comparable concerning demographic and perioperative variables. However, since the cannulated screws were a more "traditional" treatment option, the follow-up time for the screw group appeared to be significantly longer. The complication rate for avascular necrosis was insignificantly lower in patients treated with cannulated screws. We found a statistically significant association between PFLP and non-unions. Overall complication rates in Pauwels' I and II fractures did not differ significantly between groups. However, the incidence of complications increased significantly in Pauwels' type III fractures, where PFLP also tended to have a significantly increased complication rate. Although the above biomechanical studies reported high stiffness and durability of PFLP in Pauwels' type III fractures, current clinical results did not support their findings. We found that reduction quality is an essential factor for radiological outcomes. Poorly reduced fractures resulted in a statistically significant increase in complications. Nevertheless, both implants were comparable in terms of their reduction quality. We did not find any screw or plate breakage in either group. Clinical outcomes were better in patients treated with cannulated screws. This finding can be attributed to the high incidence of complications, particularly non-union, in the plate group.

Berkes et al.[25] investigated 18 fractures fixated with PFLP. The mean age was 71.7 years, and only three patients had a Pauwels' III fracture. They reported seven out of 18 implant-related failures with five broken screws. Compared to our study, they had a slightly higher number of non-union cases (38.9%). In their experimental group, the Harris Hip scores were 67.9, comparable to our study. However, they showed significant differences compared to the historical control group. Their study group consisted of patients with high mean age, but the age factor did not differ from the control group. They concluded that length stable fixed-angle locking plates interfere with the fracture site's micro-motion, which is necessary to overcome any distraction and resorption. This phenomenon is against the bony union.

Lin et al.[26] conducted a prospective study with 41 patients treated with PFLP. They classified patients according to Garden classification. In contrast to our

study, the complication rate for avascular necrosis was higher than the non-union rate. The same locking plate was used in the study by Wang et al.[27] compared to multiple cannulated screws. Non-union, overall complication rate and the degree of femoral neck shortening were significantly higher in patients treated with multiple cannulated screws ($p<0.05$), whereas there were no significant differences in HHS and implant failures. Unfortunately, these two studies mentioned above did not provide any information on the verticality of the fractures.

Wang et al.[28] performed a retrospective study examining 45 patients with Pauwels' type III fractures treated with a proximal femoral hollow locking plate. They reported no construct-related complications. Ninety-three percent of the study population had bone healing. With a score of 92.1, they reported better Harris Hip Scores than our study groups. It is worth noting that all the cases in their series had anatomical reduction with a normal Garden's index, which could be the reason for this report's better radiological and clinical outcomes compared to our current study. Recent finite element analysis by Wang et al.[29] demonstrated that the postoperative spatial displacement results in increased displacement at the fracture site, stress, and strain of the proximal femur at follow-up. They concluded that poor reduction quality increases the risk of femoral head necrosis and re-fracture rates.

The limitation of this current study is its retrospective design and small population size. Therefore, prospective and randomized studies with a larger sample of displaced Pauwels' type III fractures should be conducted to accurately compare these implants concerning radiological and clinical outcomes.

Despite encouraging biomechanical studies favoring PFLPs, clinical outcomes have not been as expected. Therefore, particular attention should be paid to patients with Pauwels' type III fractures, and every effort should be made to achieve a precise reduction.

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