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ORIGINAL ARTICLE • HIP - FRACTURES

Undisplaced femoral neck fractures need a closed reduction before internal fixation

Tatsuya Yamamoto[1] · Yoshiomi Kobayashi[2] · Hiroaki Nonomiya[2]

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Abstract

Introduction Undisplaced femoral neck fractures (UFNF) are generally treated with in situ internal fixation, and few studies have addressed the impact of closed reduction. The aim of this study was to investigate the clinical outcome of UFNF treated with internal fixation using the Hansson pinloc system after closed reduction.

Patients and methods This was a retrospective study of 40 patients who underwent internal fixation using the Hansson pinloc system after closed reduction between September 2014 and May 2016. In the present study, posterior tilt, presence of complete fracture, interval from injury to surgery, and changes in activities of daily living were statistically analyzed to investigate the association between nonunion and late segmental collapse (LSC).

Results Five cases each of nonunion and LSC were identified. The frequency of LSC was significantly higher in patients with preoperative posterior tilt $\geq 20°$ ($p < 0.05$). The risks of nonunion and LSC were lower in patients with incomplete fracture ($p < 0.05$) and fixation within 48 h ($p < 0.05$). Of the 40 patients, 34 were categorized in the sufficient reduction group fixed with posterior tilt $\leq 5°$. Secondary operation rate was lower in the sufficient reduction group (5/34 cases) than in the insufficient reduction group (3/6 cases).

Discussion The fixation timing < 48 h decrease the risk of fracture healing complications and sufficient reduction may reduce the risk of secondary operation. Preoperative posterior tilt $\geq 20°$ and complete fractures on CT scans were related to poor prognosis.

Keywords Undisplaced femoral neck fractures · Posterior tilt · Hansson pinloc system · Closed reduction · Late segmental collapse · Nonunion

Introduction

Undisplaced femoral neck fractures (UFNF) are classified using Garden's classification into stages I–II according to preoperative radiographs [1]. UFNF are generally treated with in situ internal fixation (without reduction) [2–4]. Nonunion and late segmental collapse (LSC) are fracture healing complications necessitating conversion to hip arthroplasty considering the long-term outcome of internal fixation [2, 5–7]. For displaced femoral neck fractures, residual retroversion deformity is the risk factor for nonunion and LSC; therefore, reduction quality has a significant effect on good outcome [8, 9]. Compared to displaced fractures, few studies have been conducted to evaluate the significance of retroversion deformity in UFNF.

Fixation for UFNF had originally been performed with devices like two parallel Hansson hook pins, three cancellous screws, and sliding hip screw [10–14]. However, rotational resistance against fracture displacement was inadequate by using these techniques, and therefore, several implant failures like cutout or displacement which resulted in secondary operation have been reported [15], while the Hansson pinloc system was developed to provide mechanical stability for rotational displacement during fracture healing. It consists of three pins locking into a plate. As a result, it

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✉ Tatsuya Yamamoto
tacchan.0517@gmail.com

[1] Department of Orthopaedic Surgery, Saiseikai Yokohamashi Tobu Hospital, 3-6-1, Shimosueyoshi, Tsurumi Ward, Yokohama, Kanagawa 230-0012, Japan

[2] Department of Orthopaedic Surgery, Japanese Red-Cross Shizuoka Hospital, Shizuoka, Japan

can create stability against rotation of the femoral head. Few studies on the importance of the reduction prior to the surgery exist and there is no literature describing the difference between in situ and closed reduction in UFNF.

Considering the risk of complication, time to surgery is also an important factor. Previous reports revealed the delay of internal fixation of more than 24 h increase the odds of nonunion [16]. Early reduction of displacement is preferable for shortening avascular time of femoral head.

Accordingly, here we investigated the clinical outcome of UFNF treated with internal fixation after closed reduction with analysis between the time to surgery and fracture healing complication.

Patients and methods

Records of 53 patients who underwent internal fixation for UFNF were retrospectively reviewed between September 2014 and May 2016. There were 13 patients lost to follow-up mainly due to diseases unrelated to the trauma. Forty patients followed up for at least 6 months were available for analysis. The patients included 6 males and 34 females with an average age of 78.0 years (range: 37–94 years). The mean follow-up period was 1.7 years. All UFNF (classified as Garden I or II) with surgical indication were treated with internal fixation using the Hansson Pinloc System (Stryker, Mahwah, New Jersey, USA) at our institution. Closed reduction on a traction table was initially conducted by traction and internal rotation, eventually compression on AP direction was performed by surgeon. In addition, retroversion deformity was reduced by putting anteroposterior pressure on the hip joint. After the reduction, internal fixation was achieved using the Hansson pinloc system (Fig. 1). Patients were allowed full weight bearing from the day following operation. Plain radiographs and computed tomography (CT) scans were performed before and after the operation. Patients were asked to return for plain radiographs and magnetic resonance imaging (MRI) follow-up at 6, 12, and 24 months postoperation.

The Garden classification of femoral neck fracture is one of the most commonly used for fracture type assessment. In this classification, an incomplete or valgus impacted fracture was classified as type I, and a complete fracture without displacement as type II [1]. However, it was difficult to differentiate all UFNF into types I or II because there are a lot of complete fractures with valgus deformities [17]. Therefore, patients were allocated into two groups depending on the presence of complete fracture with CT scans (Fig. 2). The degree of displacement was assessed using the posterior tilt on the lateral radiographs for retroversion measurement, and the posterior tilt was categorized into two groups: <20 and ≥ 20 as previously described (Fig. 3) [13, 18]. Patients were

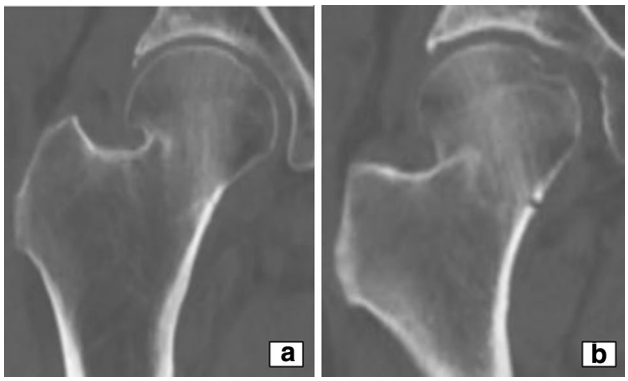

Fig. 2 Incomplete fracture (**a**) and complete fracture (**b**) on the CT scans. Fracture gaps were usually detected on the medial cortex of the femoral neck

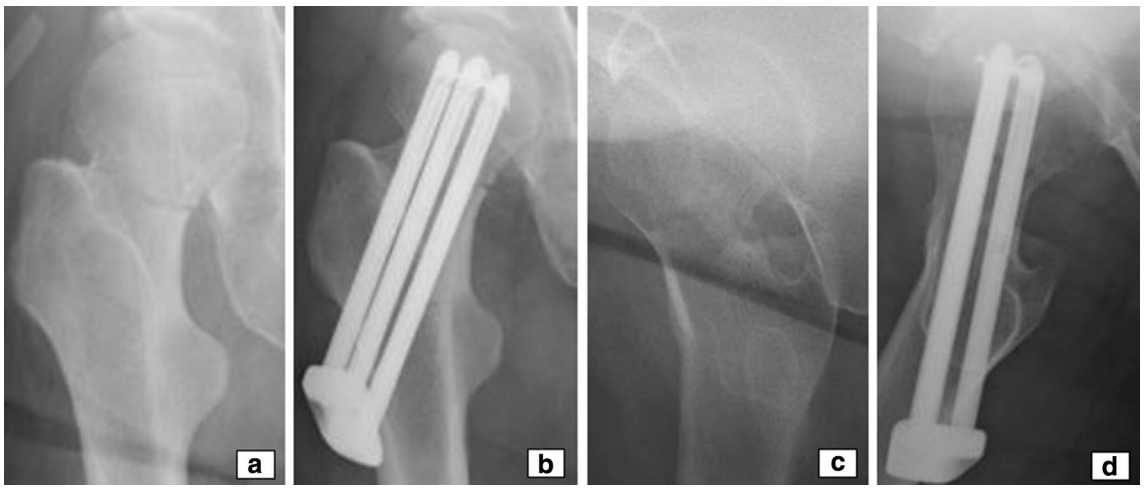

Fig. 1 Pre- and postoperative plain radiographs. Retroversion deformity was reduced after the closed reduction

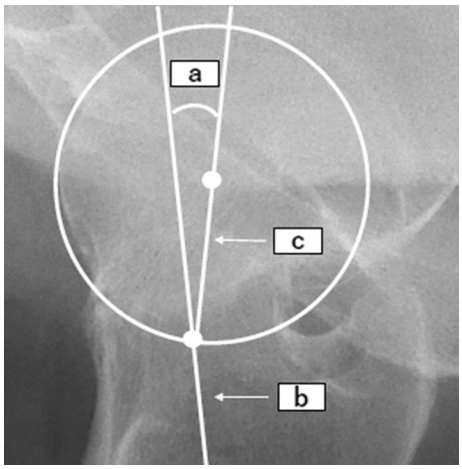

Fig. 3 The posterior tilt was defined as the angle (**a**) between the mid-column line, (**b**) and the radius column line (**c**) (Palm et al. [13])

also allocated into two groups depending on the interval from injury to surgery: (Group 1) operated within 48 h, and (Group 2) operated after 48 h. The changes in activities of daily living (ADL) were recorded before the surgery and at the final follow-up. ADL was divided into four grades: Grade IV: walking by themselves, Grade III: walking with cane, Grade II: walking with walker, Grade I: using a wheelchair. ADL deterioration was defined as a decrease in more than 1 grade.

The relationship between clinical data involving radiographic parameters and complications including nonunion and/or LSC were analyzed using the Chi-square test (Fig. 4). We defined nonunion as the state of pain caused by neck shortening with intact femoral head and fracture line. In contrast, LSC is the state of pain caused by a partially collapsed femoral head resulting from avascular necrosis [19]. The correlation between the degree of retroversion and the presence of complete fracture was analyzed using the *t* test.

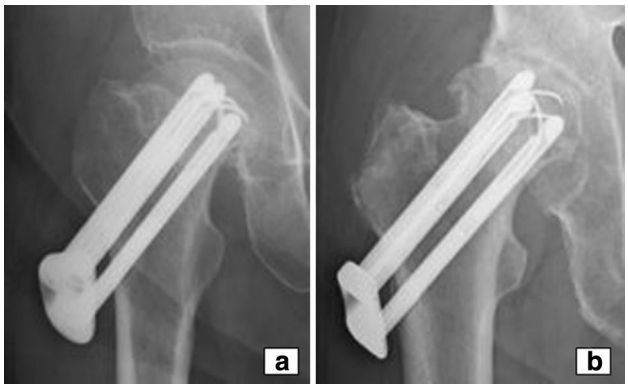

Fig. 4 Nonunion showed femoral neck shortening with intact femoral head (**a**), LSC showed the breakage of the femoral head outline (**b**)

Plain radiographs were obtained at each of the 4 points (preoperation, just after the operation, 6 months postoperation, 12 months postoperation), and the displacements were compared using the ANOVA and Bonferroni tests. We defined the sufficient reduction group as patients with posterior tilt $\leq 5°$ and the insufficient reduction group as others, secondary operation risk was compared between these two groups. Statistical significance was defined at the level of $p < 0.05$. The results are presented as means and 95% CI. Statistical analyses were performed using IBM SPSS version 24.0 (SPSS, IBM Corporation, USA).

Results

Patient demographic and radiographic parameters are presented in Table 1. There were only four patients with posterior tilt $\geq 20°$. Thirty-one patients had complete fractures. Seventeen patients underwent surgery within 48 h after injury. ADL deterioration was observed in fifteen patients. At the end of the follow-up, five cases each of nonunion and LSC were identified. The overall complication rate was 25% (10/40). The relationship between predictive risk factors and complications is shown in Table 2. Briefly, the frequency of LSC was higher in patients with preoperative posterior tilt $\geq 20°$ ($p = 0.017$). The risk of complications (nonunion and LSC) was statistically significantly higher in patients with complete fractures than in those with incomplete fractures ($p = 0.049$). Also, patients who underwent fixation after 48 h showed higher complication rates than those who underwent fixation within 48 h ($p = 0.002$). While in patients with

Table 1 Case variables of the study ($n = 40$)

Case variable	*n* (%)
Preoperative posterior tilt	
$\geq 20°$	4 (10)
$< 20°$	36 (90)
Complete fracture	
Yes	31 (77.5)
No	9 (22.5)
Time to surgery	
≥ 48 h	23 (57.5)
< 48 h	17 (42.5)
ADL	
No change	25 (62.5)
Deterioration	15 (37.5)
Complication	
Nonunion	5 (12.5)
LSC	5 (12.5)

ADL Activity of daily living, *LSC* late segmental collapse

Table 2 Risk factors for ADL deterioration and fixation failure according to preoperative posterior tilt, fracture type, and interval from injury to surgery

	ADL deterioration	Nonunion	LSC	Nonunion or LSC
Preoperative posterior tilt				
≥ 20° ($n=4$)	3	0	2	2
≤20° ($n=36$)	12	5	3	8
p value	0.102	0.426	0.017	0.224
Complete fracture				
Yes ($n=31$)	14	5	5	10
No ($n=9$)	1	0	0	0
p value	0.063	0.198	0.198	0.049
Interval from injury to surgery				
≥ 48 h ($n=23$)	11	5	5	10
≤48 h ($n=17$)	4	0	0	0
p value	0.117	0.04	0.04	0.002

ADL Activity of daily living, *LSC* late segmental collapse

incomplete fractures or fixation within 48 h, no complications were found in this cohort.

The posterior tilt was significantly higher in the complete fracture group than in the incomplete fracture group (10.8° vs. 4.0°) ($p=0.02$) (Table 3). The posterior tilt was reduced to ≤5° in 85% (34/40) of the patients. The change of posterior tilt was from 9.3° to 2.0° after the closed reduction ($p=0.01$) (Table 3). Although only 19 patients were assessed at each of the 4 points, the primary reduction of the posterior tilts was maintained until the 12-month follow-up (Fig. 5).

Secondary operation rate was 50% (3/6) in the insufficient reduction group compared to 14.7% (5/34) in the sufficient reduction group with the odds ratio of 5.8.

Discussion

In the present study, we revealed that the posterior tilt was significantly higher in the complete fracture group than in the incomplete fracture group although the sample size was not large. Generally, UFNF can be classified as Garden type I (incomplete, valgus), and type II (complete, neutral) by plain radiographs [1]. However, CT scans showed several complete fracture cases with valgus deformity even in Garden Type 1. This is one of the limitations of Garden classification. Consistent with the present study, previous studies also showed that preoperative posterior tilt ≥ 20° was a risk factor for fixation failure [13, 18]. These results suggested that most of the patients with posterior tilt ≥ 20° reached complete fracture beyond incomplete fracture even if plain radiographs showed no evidence of complete fracture. More high energy had to be added to these cases, which led to

Table 3 t test for correlation between fracture type and posterior tilt, and changes before and after the operation ($n=40$)

	Complete ($n=31$)	Incomplete ($n=9$)	p value
Posterior tilt	10.8 ± 7.7	4.0 ± 6.0	0.02
	Preoperation	Postoperation	p value
Posterior tilt	9.3 ± 7.8	2.0 ± 3.6	0.001

Fig. 5 The trajectory of transition of posterior tilt in the 19 patients who were followed up with plain radiographs at each of the 4 points

injury of blood vessels to the femoral head or decrease in blood supply due to retroversion deformity itself. In the cases of blood vessels not completely broken, early reduction should be important in revascularization of femoral head.

Although the use of traction table should stabilize the fracture site and blood vessels that would lead to make more blood flow to the femoral head, closed reduction prior to the internal fixation was not attempted previously in UFNF. Generally, fractures reduce easily before hematoma formation and retroversion deformity could be reduced partially by traction force. For these reasons, early reduction should help the recovery of blood supply that could play an important role in success of fracture healing. Our results showed that reduction and fixation < 48 h reduced the risk of nonunion and LSC, these data are compatible with these facts.

The rate of secondary operation was higher in the sufficient reduction group than in the insufficient reduction group in this cohort. Several studies reported about the reduction in displaced femoral neck fractures, not in UFNF [6, 9, 20, 21]. Those described that the varus and retroversion of the femoral neck led to worsening clinical scores and/or complications, in contrast, valgus did not significantly influence the clinical outcome [4]. Our results suggested that sufficient reduction could decrease the risk of secondary operation even in UFNF. Regarding the reduction, no previous report has reviewed the temporal change in the postoperative position of the femoral neck. We confirmed sufficient reductions (posterior tilt ≤ 5°) were acquired in 85% of patients and it prolonged 12 months postoperation. Thus, not only the early stabilization of fracture site, but also the reduction of retroversion decreased the risk of nonunion and LSC. Based on these findings, the maintenance of sufficient reduction should play an important role for good prognosis.

There are several limitations that need to be addressed regarding this study. First, the main limitation lay in the retrospective study with lower evidence level. Second, the small sample size and midterm follow-up limited broad generalization from the present study. And finally, a comparison with the postoperative nature of nonreduction group as a control group should be needed. However, the femoral neck fracture is one of the most common fractures in elderly society, to reduce the secondary surgery, our study is worth reporting as a reference to consider the closed reduction prior to the surgery.

Conclusions

We reported the clinical outcomes of UFNF treated with internal fixation after closed reduction. We conclude the fixation timing < 48 h decrease the risk of fracture healing complication and sufficient reduction may reduce the risk of secondary operation. From our results, patients with preoperative posterior tilt ≥ 20° and complete fractures on CT scans were related to poor prognosis, therefore, careful follow-ups are warranted.

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Authors' contribution TY collected and interpreted the data and wrote the initial draft of the manuscript. YK analyzed and interpreted the data and also assisted in the preparation of the manuscript. HN designed the study and critically reviewed the manuscript. All authors approved the final version of the manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work were appropriately investigated and resolved.

Compliance with ethical standards

Conflict of interest Tatsuya Yamamoto, Yoshiomi Kobayashi, and Hiroaki Nonomiya declare that there was no conflict of interest regarding this manuscript.

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