What is the fracture displacement influence to fracture non-union in intramedullary nail treatment in subtrochanteric fracture?

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ABSTRACT

Introduction: The fracture displacement in intramedullary nail in femoral subtrochanteric fracture may cause fracture non-union. We retrospectively analysed our recent experience to clear the influence about fracture displacement in intramedullary nail in femoral subtrochanteric fracture.

Materials and methods: This study includes 36 patients in the intramedullary nail group followed up for more than 12 months; these patients suffered from femoral subtrochanteric fracture from 2009.1–2014.12 in our hospital. The operation time, amount of bleeding, length of hospital stay, fracture healing time, Harris function score of hip joint, fracture displacement, TAD and postoperative complications were summarized.

Results: The average follow up time was 20.2 months, average operation time was 126 min, average amount of bleeding was 258 ml, average hospitalization was 13.1 days, average fracture healing time was 6.8 months, average fracture displacement was 1.23 cm, average TAD was 19.7 mm and average hip Harris function score was 82.5 points. Five cases suffered non-union. Only the fracture displacement degree made significant correlation with fracture non-union. All union patients had a fracture displacement less than 2.2 cm and all non-union patients had a fracture displacement more than 2.5 cm.

Conclusion: Intramedullary nail treatment must focus on fracture reduction and recovery of femoral medial support with assisted incision technique or closed cerclage wire technique when necessary. In our opinions, only the fracture displacement degree made significant correlation with bone non-union and all cases achieved bone union when it less than 2.2 cm according to our statistics. But it still need further research to find out the displacement of fracture fragments could be tolerant.

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1. Introduction

Femoral subtrochanteric fracture is not uncommon in clinical practice, especially in elderly patients, accounting for 2%–7% of all proximal femoral fractures.¹ This type of fracture remains a challenge to orthopaedic surgeons. According to the mainstream view, intramedullary nail treatment is currently the more dominant method used to subtrochanteric fractures. Intramedullary nail generally offers more advantages in terms of fixation rigidity, surgical injury, and fracture healing.² The meta-analysis of Liu et al.³ have shown that intramedullary nail offers significant advantages in reducing internal fixation failure, improving fracture healing and reducing revision surgery compared with extramedullary fixation. However, in some fracture types such as long spiral fracture, intramedullary nail fixation may need other

support fixation as wire to get perfect fracture reduction and fixation.⁴ The displacement of the proximal fragments in subtrochanteric fractures is caused by the muscle traction of the gluteus medialis and the iliopsoas. The typical deformity in subtrochanteric femur fractures is a proximal fragment that is flexed, abducted, and externally rotated. Fracture instability and regional muscle traction often render fracture reduction difficult and cause non-union of fracture and failure of internal fixation. Though the closed reduction and intramedullary nail fixation is widely accepted currently, the malreduction and fracture non-union still occurred occasionally.

Compared with diaphyseal femoral shaft fractures, subtrochanteric fracture presents significant treatment challenges. The fracture reduction in intramedullary nail sometimes could not achieve anatomical reduction with the medial buttress absent. When there is medial comminution, the implant used for fixation is subjected to high bending load. Though the nail treatment don't require fracture anatomical reduction, it is still important to get satisfactory fracture reduction for bone healing. Fracture healing could be achieved in most of these circumstances, the fracture

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non-union still happened in some nail cases when fracture malreduction. There were little reports about fracture malreduction affected fracture non-union in nail treatment. Riehl JT et al.⁵ found there was a statistically significant higher rate of delayed or nonunion when postoperative radiographs showed malreduction greater than or equal to 10° in any plane. Choi JY et al.⁶ recommended the comminution of the medial cortex and the degree of the postoperative displacement of fractures contributed to the delayed time of union. However, there was no further research about fracture non-union with fracture displacement degree in current studies. Whether the fracture displacement degree correlated with bone non-union and the fracture displacement degree which could be tolerant to fracture union still remained unknown.

We retrospectively analysed femoral subtrochanteric fracture patients, who were treated in our hospital. These patients were all treated with closed reduction of intramedullary nail. We attempted to identify the influence factors of bone non-union in intramedullary nail treatment of subtrochanteric fracture. In particular, we focus on the following aspects: (1) how to restore femoral medical support by closed reduction in intramedullary nail treatment; (2) whether the fracture displacement degree made significant correlation with fracture non-union; and (3) how much the fracture displacement degree could be tolerant after operation. We hope that this report will serve as a reference for the fracture reduction of intramedullary nail in femoral subtrochanteric fracture treatment.

2. Materials and methods

2.1. Patient demographics

The patients with femoral subtrochanteric fracture have undergone surgery in our hospital from 2009.1–2014.12 were retrospectively analysed. The inclusion criteria are as follows: (1) the fracture line is located in the area extending from the lesser trochanter up to 5 cm distal to the lesser trochanter⁷; (2) fracture time relative to the initial operation is <2 weeks; and (3) follow-up time is longer than 12 months. The exclusion criteria are as follows: (1) open fracture; (2) open reduction during operation and (3) presence of a pathological fracture. The patients and/or their families were informed that data from the case would be submitted for publication, and gave their consent.

A total of 36 patients were included in the intramedullary nail group, consisting of 26 males and 10 females, and their mean age was 45.9 years old (24–76 years). The causes of injury in these patients were as follows: tumbles in 24 cases, falls from height in 4 cases, traffic accident in 7 cases, heavy extrusion in 1 case and 6 cases showed combined injuries.

2.2. Treatment methods

The patients were admitted in our hospital after a definite diagnosis; they received routine preoperative femoral X-rays and femoral CT examination and lower limb traction was continued until surgery. The CT scan could show the displaced fracture fragments clearly and find hidden fracture line sometimes. It is helpful to make surgery plan. In addition, combined injury, if any, was managed. The Seinsheimer femoral subtrochanteric fracture classification⁸ was verified by the preoperative X-ray and CT results. The combined injury was treated in the same period or second stage depending on the patient's specific circumstances.

2.3. Surgical methods

We used long reconstruction nail (Smith & Nephew, USA) or long PFNA nail (Synthese, Switzerland) as fixation. The patients were

administered with general anaesthesia at supine position on orthopaedic radiolucent traction surgical table. The injured limb was kept in extension position by using traction, whereas the knee and hip of the healthy limb were flexed for the C arm X-ray machine fluoroscopy during operation. Closed reduction was achieved by adjusting the traction force, limb alignment and rotation. If X-ray showed good reduction, a 3–5 cm long incision proximal to the greater trochanter was created, and the greater trochanter vertex was selected to be the entry point of the guide wire. The guide wire was then inserted through the fracture line up to the distal femur. After checking that the guide wire is in position, we reamed the femur, selected the appropriate intramedullary nail to be inserted into the appropriate depth, placed the locking screws into the nail and then we checked the fracture reduction and internal fixation position again. If X-ray showed unsatisfactory reduction at first, a 1–2 cm long assisted incision was created, which was usually located near the lesser trochanter at the anterolateral side of the thigh. The fracture could always be reduced by poking, pulling and clamping, among others. If necessary, the fracture can be reduced and fixed by using the closed cerclage wire banding technique. Only X-ray showed accepted reduction, then we made the entry point and reamed femur. The intramedullary nail was then inserted routinely. We would always check X-ray to confirm a satisfactory fracture reduction during operation.

Combined injury treatment: our patients includes 2 cases of ipsilateral fracture of the calcaneus with a first-stage internal fixation operation, 2 cases of pelvic fracture and 2 cases of head injury with conservative treatment.

2.4. Postoperative treatment

The passive joint functional activities and exercises were started the day after operation, and the intensity of functional exercise were gradually increased. Partial weight-bearing functional training was started under the guidance of doctor after 2 weeks. Postoperative examinations were conducted after 1, 2, 3, 6, 9 and 12 months after operation. Femoral X-ray examination was also conducted at each review; when necessary, femoral CT examination would be performed. Sometimes our X-rays could not show standard AP view or lateral views because the patient's incorrect body position due to pain, and sometimes we need check whether there was any bone callus formation for bone union, then we would take CT scan. We use the sum of the largest fracture displacement measured at AP view and lateral view of X-rays to evaluate the malreduction. (Fig. 1), the standard clinical and radiological criteria to evaluate fracture healing time and the hip Harris joint function score to assess hip joint function. We summarized the patients' operation time, intra-operative bleeding volume, length of hospital stay, fracture healing time, fracture displacement, TAD and hip function score and postoperative complications occurrence.

2.5. Statistical analysis

Statistical analysis was performed using SPSS version 22 (SPSS Inc., Chicago, Illinois). The Chi-square test and binary logistic regression were used for univariate analysis of the categorical and continuous parameters, respectively. To account for the small sample size, significance was defined as $p < 0.01$. A multivariate analysis was performed with all the parameters with $p < 0.05$ in the univariate analysis. A backwards likelihood ratio was performed to identify the best-fit model, with the entry set at $p < 0.05$ and removal at $p > 0.10$.

3. Results

The average follow-up time was 20.2 months (12–45 months). According to Seinsheimer fracture classifications,

Fig 1. The method of fracture displacement measurement on AP view and lateral view X-rays. A. the black arrow showed the largest displacement between distal and proximal fracture site on AP view X-ray. B. the black arrow showed the largest displacement on lateral view X-ray. The total fracture displacement degree = A + B.

the group was divided into type II (3 cases), type III (14 cases), type IV (15 cases) and type V (4 cases). A total of 16 cases were treated with PFNA and 20 cases were treated with long reconstruction nail. The average operation time was 126 min (50–300 min), the average intraoperative bleeding volume was 258 ml (50–600 ml), the average hospitalization stay was 13.1 days (6–30 days), the average fracture healing time was 6.8 months (3–17 months), the average fracture displacement was 1.23 cm (0–3.2 cm), the average TAD was 19.7 mm (11–41 mm) and the average hip function score was 82.5 points (66–93 points). During the last follow-up, internal fixations in four patients were removed. Fourteen patients underwent small incision-assisted reduction and five patients underwent closed cerclage wire fixation. Totally 5 cases suffered fracture non-union including 2 cases received augmentative plate treatment (Fig. 2) and 3 cases received locking plate exchange treatment at 6 months after operation. During last follow-up, all of patients achieved bone healing and could walk with a load. No case suffered from wound infection, deep vein thrombosis and other complications. In addition, no other serious systemic complications occurred.

In our analysis, Statistical significance was observed only with fracture displacement ($p < 0.001$) and hip harris score ($p = 0.001$), other parameters made no significant in the univariate analysis. (Table 1) The multivariate model included age, gender, and all parameters with $p < 0.01$ in the univariate analysis, and statistical significance was observed with fracture displacement ($p < 0.001$) and hip harris score ($p = 0.002$) again. (Table 2) Obviously, the hip harris score was the result of bone union or non-union but not the influence factor. Thus, only the fracture displacement only made significant correlation with bone non-union. According to our statistics, all union patients had a fracture displacement less than 2.2 cm and all non-union patients had a fracture displacement more than 2.5 cm.

4. Discussion

The femoral subtrochanteric area is subjected to concentrated biomechanical stress and is very vulnerable to internal fixation mechanical failures. Based on its anatomical characteristics, it was easily to cause fracture non-union. The treatment of non-union algorithm had been detailed introduced,⁹ and we should avoid the non-union happened. However, non-union still existed in intramedullary nail treatment and there were little reports about fracture malreduction affected fracture union. Our research included various risk factors for nonunion, including age, sex, nail type, classifications of fractures, hospitalization days, operative time, bleeding, TAD and the degree of fracture displacement. Only the degree of fracture displacement made significant correlation. Therefore, it is critical to achieve an excellent fracture reduction in the operation.

Previous reports have indicated that the occurrence rates of non-union and varus deformity were elevated as the high degree of initial fracture displacements, suggesting poor prognoses.¹⁰ The comminution of the medial cortex is known to result in varus deformity and delayed union and failure of internal fixations suggestive of poor prognoses.^{11,12} The medial buttress is fundamental for the stability of the osteosynthesis.¹³ Therefore, maintenance of the continuity of the medial cortex and the reduction of all possible fracture fragments is recommended.¹⁴ Riehl JT et al.⁵ showed malreduction greater than or equal to 10° in any plane and Choi JY et al.⁶ recommended the comminution of the medial cortex and the degree of the postoperative displacement of fractures contributed to fracture non-union. When fracture displacement degree increased, the medial buttress lost more seriously. In patients with displaced fracture fragments, stress on the implant is higher and healing time of bone is longer because of the large fracture gap; both predisposing to implant failure. In Chang SM et al.¹⁵ research, there was positive medial cortical

Fig. 2. A patient suffered fracture non-union after long reconstruction nail treatment, 58 years, female. A. X-ray shows comminuted fracture and severe displacement. B&C. X-rays after operation showed unsatisfactory reduction. The total displacement was 3.2 cm by the black arrow measured on the AP view and lateral view X-rays. D&E. After 6 months, there was still no sign of bone healing. F&G. The augmentative plate was used in the revision operation. Bone union was achieved at 4 months after revision operation.

support about subtrochanteric fracture which could resist to the varus stress and provide a good mechanical environment for fracture healing. The fracture displacement degree could represent the medial buttress, thus it made significant correlation with fracture non-union and the displacement degree should not

exceed some range. In our research, we found the maximum fracture displacement could be tolerant was 2.2 cm according to our statistics.

Although the posteromedial cortex alignment is the key for successful reduction, nails used today do not have the ability to purchase the lesser trochanteric fragment. In the treatment of comminuted fracture, the intramedullary nail may lead to separation and displacement of fracture fragments and fracture non-union.^{16,17} There were lots of closed reduction techniques for reduction.¹⁸ The assisted small incision for minimally invasive fracture reduction was widely used. MR Juan et al.¹⁹ used small assisted incision to treat femoral subtrochanteric fracture with all of 26 patients achieved bone healing. In our case, 14 patients were treated with assisted small incision, and the clinical results were satisfactory. Generally, we can use specific surgical instruments such as Hoffmann puller, periosteal elevator and reduction clamp, through the incision to reduce fracture by poking, clamping and other operations to restore the femoral medial support. In our series, five patients received closed cerclage wire banding for fracture reduction and fixation with successful bone healing. Cerclage wire fixation in intramedullary nail by means of the closed wire technique is currently permissible, and this approach will not lead to non-union.²⁰ There were several reports about cerclage wire by closed technique with good clinical results.^{21,22} It was recommended that the cerclage wire by closed technique would not break the vascular supply. Therefore, in such femoral

Table 1
Univariate analysis. Significant p-values ($p < 0.01$) are indicated in bold.

Factor	All	Union (n = 31)	Nonunion (n = 5)	p-value
Age (years)	45.8	45.9	45.4	0.943
Gender	36	31	5	0.525
Male	26	23	3	
Female	10	8	2	
Nail type	36	31	5	0.835
PFNA	16	14	2	
LRN	20	17	3	
Seinsheimer type				0.053
Type II	3	3	0	
Type III	14	13	1	
Type IV	15	13	2	
Type V	4	2	2	
Fracture displacement(cm)	1.23	0.98	2.76	<0.001
Hospitalization(days)	13.9	13.3	17.8	0.156
Operative time(min)	145.8	138.4	192	0.065
Bleeding(ml)	243.5	216.3	412	2.081
Harris score	83.5	85	74.2	0.001
TAD(mm)	19.7	19.7	20.0	0.922

Table 2 Multivariate analysis Significant p-values ($p < 0.05$) are indicated in bold.

Factor	p-value	Odds ratio	95% Confidence intervals for odds ratio
Age (years)	0.941		
Gender	0.733		
Harris score	0.002		–0.039–0.010
Fracture displacement(cm)	<0.001	0.161	0.211–0.407

subtrochanteric fracture with difficult closed reduction, a small assisted incision could be used for fracture reduction, especially when recovering the femoral medial support. Closed cerclage wire by closed technique could be adopted for fracture reduction and fixation when necessary.

The limits of our study: this work is a retrospective study. All patients were treated in our hospital, and a chance for a bias in data collection exists. The number of patients who were followed-up was insufficient. Moreover, there might be a measurement error existed in some patients in our method due to non-standard X-rays and measure technique. The measure method might need improvement in the further research according to our statistics.

5. Conclusion

Intramedullary nail treatment must focus on fracture reduction and recovery of femoral medial support with assisted incision technique or closed cerclage wire technique when necessary. In our opinions, only the fracture displacement degree made significant correlation with bone non-union and all cases achieved bone union when it less than 2.2 cm according to our statistics. But it still need further research to find out the displacement of fracture fragments could be tolerant.

Conflict of interest

None.

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