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Original article

Effects of third fragment size and displacement on non-union of femoral shaft fractures after locking for intramedullary nailing☆

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ABSTRACT

Background: The femoral shaft fractures with large fragments makes anatomical reduction challenging and often results in non-union. In some studies, the degree of fragment displacement was reported to have affected non-union, but the association between the one fragment size and degree of displacement has not been fully clarified. Therefore we performed a retrospective study to assess: (1) the more influential factor of non-union: the degree of fragment displacement, or the fragment size? (2) the non-union rates according to different sizes and degrees of displacement.
Hypothesis: The degree of displacement is the more potent factor of non-union than the third fragment size in femoral shaft fractures.
Patients and methods: We assessed retrospectively 64 cases, which could be followed up for longer than one year. Fragments were divided according to the length of their long axis into three groups: group A (0–3.9 cm), (n = 21); group B (4–7.9 cm), (n = 22); group C (8 cm or more), (n = 21). Fragment displacement was also assessed in the proximal (P) or distal (D) end to the nearest cortex of the femoral shaft, and divided into the following groups: group P1 (n = 44) or D1 (n = 47), (0–9 mm); group P2 (n = 10) or D2 (n = 11), (10–19 mm); group P3 (n = 7) or D3 (n = 3), (20–29 mm); and group P4 (n = 3) or D4 (n = 3), (30 mm or more).
Results: The bone union rate was 86% in the small (less than 8 cm) fragment groups and 71% in the large (8 cm or more) fragment group (P = 0.046). With respect to the degree of displacement, the union rate was lower (P = 0.001) and the average union time was longer (P = 0.012) in the 20 mm or more group for both the proximal fragment part and the distal fragment part (P = 0.002, P = 0.014). A logistic regression analysis underlined the displacement in the proximal site (OR: 0.298, 95% CI: 0.118–0.750) as in the distal site (OR: 0.359, 95% CI: 0.162–0.793) as a larger effect on union rate than the fragment size that as no effect in logistic regression (OR 3.8, 95% CI: 0.669–21.6).
Conclusion: Non-union develops significantly more frequently in femoral shaft fractures with fragments 8 cm or longer or when the displacement in the proximal area is 20 mm or greater and 10 mm or greater in the distal area during the intramedullary nailing procedure. Regarding union rate, the degree of displacement has more influence than the third fragment size in femoral shaft fractures.
Level of evidence: IV, retrospective cohort study.

1. Introduction

Intramedullary nailing is widely used for femoral shaft fractures due to its high union rate and its low infection and malunion rates. According to the Arbeitsgem-einschaft für Osteosynthesefragen/Orthopedic Trauma Association/32-B/32-C (AO/OTA 32-B/32-C) classification system, femoral shaft fractures with third fragments account for 10–34% of all femoral shaft fractures [1,2]. In fractures with large fragments, a space remains between the fragments after closed reduction, which makes anatomical reduction challenging and often results in non-union [1,2]. In a previous study, non-union was reported in 6% of all femoral shaft fractures with intramedullary nails [3]. In another study, non-union or delayed union, which required revision surgery, developed in 12.5% of all fractures with intramedullary nails [1].

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Both the size and degree of displacement of third fragments have been reported to be associated with non-union [1,3]. However, the specific fracture size and degree of displacement that lead to non-union have not yet been determined. Therefore, we performed a retrospective study to assess:

- the more influential factor of non-union: the degree of fragment displacement, or the fragment size?
- the non-union rates according to different sizes and degrees of displacement.

We hypothesized the degree of displacement is the more effective factor of non-union than the fragment size in femoral shaft fractures.

2. Patients and Methods

2.1. Patients

Retrospective analyses without control group were conducted for the 64 cases of the 147 femoral shaft fracture patients who underwent surgery between January 2004 and April 2013, which could be followed up for longer than one year. A femoral shaft fracture was defined as a fracture in the area beginning 5 cm distal to the lesser trochanter and ranging to 5 cm proximal to the adductor tubercle [4]. Patients with pathologic fractures, open fractures, previous surgeries, and fractures in other areas such as cervical, peri-trochanteric, subtrochanteric, and distal fractures were excluded. Patient medical records and radiologic images were analyzed. Eleven patients were female and 53 were male. The mean patient age was 42.9 ± 18.6 years (range: 17–84 years). Of the 64 patients, 32 had right-side fractures, and 32 had left-side fractures. Of them, 15 (23.4%) were smokers. The numbers of injuries according to cause are listed in Table 1.

2.2. Surgical technique

The average time interval between injury and operation was 4.2 ± 3.4 days. Reamed nails were used as intramedullary nails in all the surgeries. Distal screws were used for fixing both static and dynamic holes. Nailing was performed in all the cases after closed reduction was completed. ROM was initiated immediately after the surgery. Partial weight bearing training was conducted with a 10-kg-increase a week for six weeks after callus formation was observed upon completion of the non-weight-bearing ambulation exercise using crutches.

Table 1
Demographic data for the patients with femoral shaft fractures.

Age (mean ± SD)	42.9 ± 18.6 (range: 17–84 years)
Gender	
Male, *n* (%)	53 (82.8)
Female, *n* (%)	11 (17.2)
Side	
Right, *n* (%)	32 (50)
Left, *n* (%)	32 (50)
Smoking	
Smoker, *n* (%)	15 (23.4)
Non-smoker, *n* (%)	49 (76.6)
Injury mechanism	
Fall, *n* (%)	7 (10.9)
Motor vehicle accident, *n* (%)	18 (28.1)
Car accident, *n* (%)	25 (39.1)
Pedestrian accident, *n* (%)	12 (18.8)
Sports injury, *n* (%)	2 (3.1)

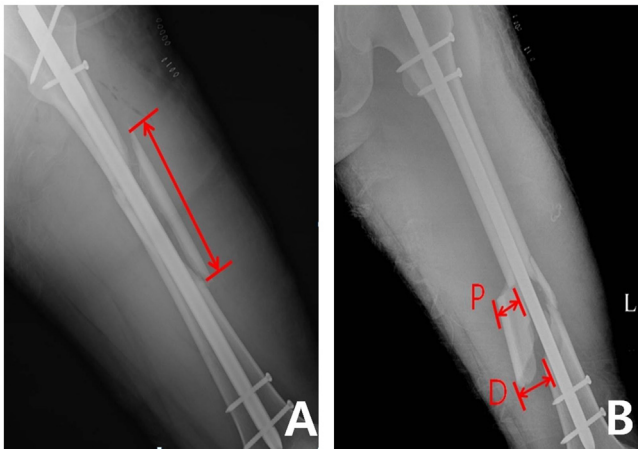

Fig. 1. Assessment of fragment length and displacement. Fragment size was determined by measuring the long axis of the fragment. The degree of fragment displacement was determined by measuring the perpendicular distances of the proximal and distal ends of the fragments to the nearest cortex of the femoral shaft. A. Measurement of fragment size. B. Measurement of fragment displacement.

2.3. Method of assessment

The size of each fracture fragment was determined by measuring the length of its long axis using plain radiographic images. Fragments were divided into the following groups according to axis length: group A (0–3.9 cm), (n = 21); group B (4–7.9 cm), (n = 22); group C (8 cm or more), (n = 21) (Fig. 1). Fragment displacement was measured by determining the perpendicular distance of the proximal (P) or distal (D) end of the fracture to the nearest cortex of the femoral shaft. The longest perpendicular distances between the P tips and the D tips of the fragments, as shown in the anteroposterior (AP) and lateral radiographic images, were measured (Fig. 1). Fractures were then divided into the following groups: group P1 (n = 44) or D1 (n = 47), (between 0–9 mm); group P2 (n = 10) or D2 (n = 11), (between 10–19 mm); group P3 (n = 7) or D3 (n = 3), (between 20–29 mm); and group P4 (n = 3) or D4 (n = 3), (30 mm or more). We also investigated union rate according to fracture fragment shape. There are several types of third fragment. For example, rotated type, inverted type, or transversely positioned type nearby cortical bone. We compared non-union rate of fracture with certain shape in each group.

Bone union was defined as bone continuity in 3 or more of the 4 cortical bone surfaces, as observed in femoral AP and lateral radiographic images (Fig. 2). Radiographic bone union rates and times according to fracture size and degree of fragment displacement were investigated. Non-union of the fracture was defined as the state in which disturbed consolidation of a fracture that needs re-operation or a prolonged healing time of more than 12 months or more [5]. In this study, non-union means non-union of the fracture itself, not that of the third fragment. Meaningful incidence of non-union was defined as non-union of 20% or more fractures; significant incidence of non-union was defined as non-union of 50% or more fractures (Fig. 3).

2.4. Statistical analysis

Mann-Whitney *U*-test was used to determine statistical differences between groups. Kruskal-Wallis one-way analysis was used to verify the significance of differences between the average of the subordination variable and the independent variable, when more