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The fracture sites of atypical femoral fractures are associated with the weight-bearing lower limb alignment

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ABSTRACT

Purpose: Atypical femoral fractures (AFFs) are stress-related fractures that are speculated to associate with long-term treatment with bisphosphonates for osteoporosis. A history of AFF is a high risk factor for the development of a subsequent AFF in the same location of the contralateral femur, suggesting that a patient's individual anatomical factor(s) are related to the fracture site of AFFs. In this study, we investigated the radiographs of fourteen AFFs (four bilateral fractures among ten patients) treated at six hospitals associated with our university between 2005 and 2010. The fracture site and standing femorotibial angle (FTA), which reflects the mechanical axis of the lower limb, were measured on weight-bearing lower limb radiographs. The fracture site and FTA of patients with typical femoral fractures (TFF) were compared to those of patients with AFFs. The correlations were examined using Spearman's rank correlation coefficients. The fracture locations in the femora were almost the same in the patients with bilateral AFFs. There was a positive correlation between the fracture site and the standing FTA in the patients with AFFs ($r = 0.82$, 95% confidence interval; 0.49 to 0.94), indicating that the larger the standing FTA (varus alignment), the more distal the site of the fracture in the femur. The FTA of the patients with atypical diaphyseal femoral fracture were significantly larger compared to that of those with not only atypical subtrochanteric fractures but also TFFs. In conclusion, the fracture sites of AFFs are associated with the standing lower limb alignment, while those of TFFs are not.

Introduction

Atypical femoral fractures (AFFs) are becoming an issue due to their relationship with long-term administration of bisphosphonates (BPs) [1–5]. Although this type of fracture can occur anywhere in the femoral bone from just beneath the lessor trochanter to the femoral shaft [6,7], it remains unclear how the fracture site of an AFF is determined [8–11]. The patterns in the radiological findings of AFFs, such as cortical thickening, beaking and flaring of the lateral cortex of the femoral shafts, clearly indicate that this type of fracture is caused by tensile failures of the lateral cortex of the femoral shaft [6,12]. In addition to these radiological features, bilateral fractures are one of the clinical characteristics of patients with AFFs [6,10,13] and occur in the same anatomical location in most cases of bilateral AFFs [10], suggesting that individual factor(s) determine the fracture sites of AFFs. These clinical features indicate that AFFs develop due to fatigue failure mechanisms and are related to altered bone tissue properties as a result of accumulation of microdamage as well as altered adaptations to mechanical forces, that may be related to BP treatment and/or other conditions that cause bone fragility. We hypothesized that the fracture site of AFFs is associated with the weight-bearing alignment of the lower limb.

In this study, we analyzed the standing alignment of the lower limb in patients with AFFs and typical femoral fractures (TFFs) and found an

Abbreviations: AFF, atypical femoral fracture; TFFs, typical femoral fractures; BPs, bisphosphonates; FTA, femorotibial angle; FN, neck fracture; IT, intertrochanteric femoral fracture; ST, subtrochanteric fracture; D, diaphyseal fracture; SLE, systemic lupus erythematosus; PM/DM, polymyositis and dermatomyositis.

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association between the fracture site and the weight-bearing alignment of the lower limb in patients with AFFs.

Methods

Objectives and definition of AFFs

A flow chart of this study is shown in Fig. 1. We retrospectively reviewed the patient admission records of the orthopedic wards of six hospitals associated with our university in Japan between 2005 and 2010 [14]. We reviewed the radiographs of all patients with hip fractures (n = 2238, femoral neck fractures, intertrochanteric fractures, and subtrochanteric fractures) and diaphyseal femoral fractures treated at these hospitals. These six hospitals consisted of four university-associated hospitals and two university-associated municipal hospitals. Subtrochanteric femoral fracture was defined as a fracture located within 5 cm distal to the lesser trochanter [15]. We defined an AFF as a fracture with all major features, in accordance with the previously described definition of AFF [6]. All the patients with AFF in this study also fulfilled the revised AFF definition [7]. Between 2005 and 2010, fourteen AFFs were observed. Four patients had AFFs on both sides; therefore, a total of 10 patients were observed during this period. With regard to TFFs, one-hundred forty-two patients with TFFs were treated in the university hospital, one of the six hospitals included in this study, during this period. Forty-four [twenty-eight were either femoral neck or intertrochanteric fracture (FN and IT, respectively), six were subtrochanteric fracture (ST), and the remaining ten were diaphyseal fracture (D)] among 142 patients with TFFs were undertaken radiographs of their lower limb for the purpose of following the fracture healing and/or checking lower limb alignment. Two TFFs who had high-energy fractures were excluded. For the definition of collagen disease, the diagnosis of rheumatoid arthritis, systemic lupus erythematosus (SLE), and polymyositis and dermatomyositis (PM/DM) was made by the rheumatologists who managed the patients based on the American College of Rheumatology defined criteria for SLE [16] and Peter–Bohan's criteria for PM/DM [17,18]. Among the patients with AFFs, five patients were diagnosed with collagen disease (three patients with SLE and two patients with PM/DM) and had long-term use of glucocorticoids (22.3 years on average).

Measurement of the fracture site in the femur using radiograph

To measure the site of the AFFs in the femur, we measured both the femoral full length [A] and the length from the proximal end of the femur to the location of the lateral cortex of the AFF [B]. The femoral full length was measured from the top of the femoral head to the distal end of the medial femoral condyle, as previously described [19]. The ratio of [B]/[A] was used as a measure of the fracture site in the femur (Fig. 2).

Weight-bearing radiographs and measurement of the femorotibial angle (FTA)

To examine the weight-bearing alignment of the lower limb, standing radiographs of the lower limbs were obtained in the patients with AFFs. The standing femorotibial angle (FTA) was measured in the anteroposterior view, as previously described [20,21]. The FTA is the lateral angle of the intersection between the femoral axis and the tibial axis on an anteroposterior radiograph (Fig. 3) [22]. In patients with normal findings, the large joints of the lower limb are aligned on a straight line that represents the mechanical longitudinal axis of the leg, the Mikulicz line (Fig. 3) [23]. This line stretches from the hip joint (the center of the head of the femur) through the knee joint (the intercondylar eminence of the tibia) and down to the center of the ankle (the ankle mortise, the fork-like grip between the medial and lateral malleoli). In the tibial shaft, the mechanical and anatomical axes coincide; however, the femoral shaft diverges 2–6°, resulting in an FTA of 174–178° in a leg with a normal axial alignment [24]. One of fourteen AFFs was excluded from the FTA analysis because FTA was apparently altered after internal fixation thereby decreasing confidence of radiological measures after surgery. Therefore, thirteen AFFs were included in FTA analysis. The 95% confidence interval (CI) of the mean value and the 95% prediction interval of the standing FTA in Japanese populations (n = 5860, 40 years or older) were from 175.1° to 178.0° and 168.6° to 184.6°, respectively [25]. The intra-observer reproducibility (YS) of the FTA was measured at separate times for fourteen patients [interclass correlation coefficient (ICC): 0.97 (95% CI: 0.86–0.99)]. The inter-observer reproducibility was measured by two observers (YS and MI) who conducted 14 examinations [ICC: 0.98 (95% CI: 0.88–0.99)].

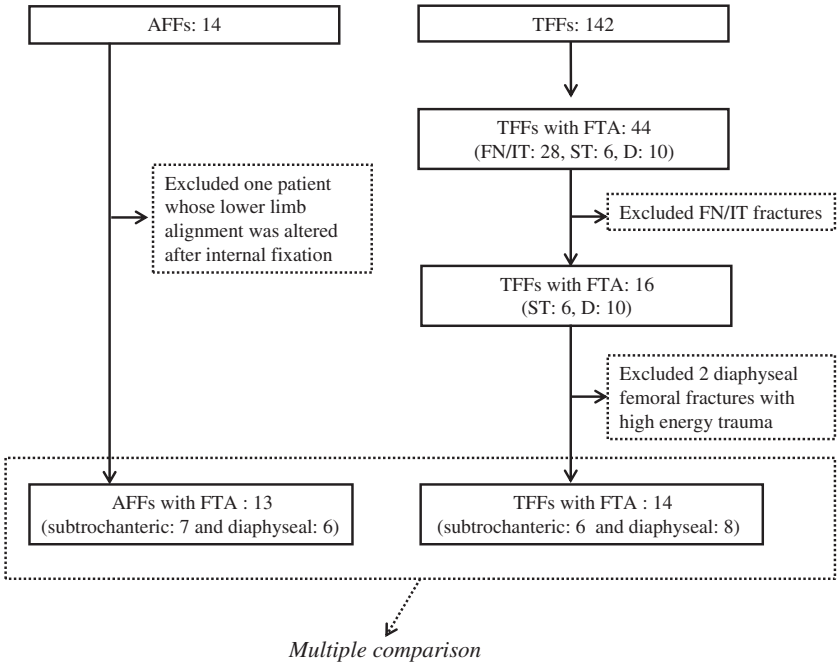

Fig. 1. Methodological flow chart for the comparison of lower limb alignment between patients with AFFs and those with TFFs.