

Lateral fixation: an alternative surgical approach in the prevention of complete atypical femoral fractures

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Abstract Little evidence is available on how to treat incomplete atypical fractures of the femur. When surgery is chosen, intramedullary nailing is the most common invasive technique. However, this approach is adopted from the treatment of other types of ordinary femoral fracture and does not aim to prevent the impending complete fracture by interrupting the mechanism underlying the pathology. We suggest a different surgical approach that intends to counteract the underlying biomechanical conditions leading to a complete atypical fracture and thus could be better suited in selected cases. Here, we share an alternative surgical approach and present two cases treated accordingly.

Keywords Atypical fracture · Femoral fracture · Bisphosphonate · Osteoporosis · Fracture prevention

Introduction

On plain radiographs, incomplete atypical femoral fractures (AFFs) can be seen as a horizontal radiolucent line confined to the lateral cortex of the affected femur (Fig. 1a).

Further progression of the pathology leads to an extension of the crack medially, perpendicular to tensional forces in the femur. Ultimately, a complete fracture occurs involving the medial cortex with a typical spike [1]. The incomplete fracture is likely the most solid evidence of a pathological process already initiated. It is among the very few warning signs that may be presented to a healthcare provider and offers a window of opportunity in which a complete atypical fracture can still be prevented.

Despite previous concerns of delayed healing, several studies have reported positive outcomes for surgical treatment of complete AFFs [2, 3]. In contrast, there is little doubt that the ability to heal is somehow compromised in incomplete fractures [4, 5]. Healing rates for incomplete fractures treated without surgical fixation are low [6–8], and there are cases that have lasted for years without healing, despite cessation of bisphosphonate treatment [9].

Surgical fixation is successful in the treatment of incomplete AFFs [6, 10–12], and in this context intramedullary nails (IMNs) (Fig. 1b) are widely considered [6, 10] the surgical treatment of choice. However, the choice of IMNs is largely based on its empirical merits rather than being a surgical technique addressing the mechanism of AFFs. Here, we present an alternative surgical approach according to biomechanical considerations. The approach is tailored to counteract the mechanical forces that might result in the formation of a complete fracture and may be considered for patients with severe femoral curvature (Fig. 2a) or in patients with preexisting joint implants of the hip or knee.

In humans, the mean radius of curvature of the femur is 112 cm (SD = 26) [13]. However, the degree of individual variation is large and strongly influenced by ethnicity [13, 14]. Differences in the presence of a significant curvature relative to ethnicity have also been observed in patients with AFFs, ranging from 25% for females in Sweden to

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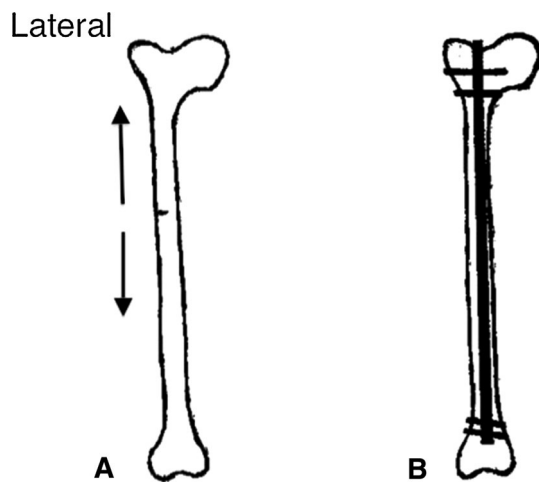


Fig. 1 **a** Schematic drawing of an incomplete fracture confined to the lateral side of a femur with a centered axis (no curvature). Tensile forces applied to the lateral cortex are outlined (arrows). **b** Schematic drawing of the same femur as in **a** that was provided prophylactic treatment with an intramedullary nail (IMN) to prevent future completion of the atypical fracture

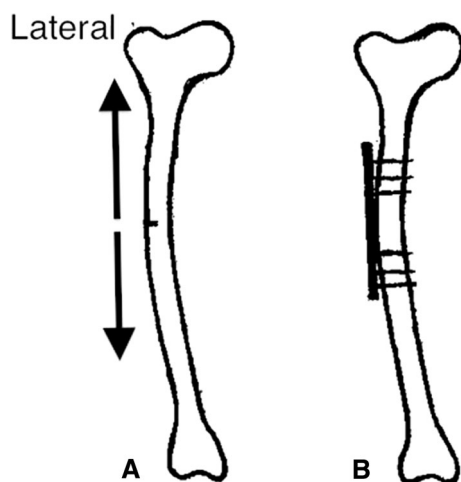


Fig. 2 **a** Schematic drawing of a curved femur with incomplete fracture confined to the lateral side of the bone. Note: increased tensile forces (arrows) are applied to this femur compared with one with a centered axis (Fig. 1a). Because of the prominent curvature of this femur, it would be difficult to insert an intramedullary nail (IMN) (**b**) without the risk of causing further injury to the architecture of the bone. **b** The curved femur with an incomplete fracture that was provided prophylactic treatment with lateral fixation according to the present approach. The plate is positioned with six bicortical screws

45% for females in Singapore [3]. The current designs of IMNs are straighter than the average human femur, leading to a higher risk of cortical impingement with increasing

curvature [15–18]. The mismatch may also lead to iatrogenic fractures during insertion of the nail, malalignment of the bone and delayed union [19, 20]. Such iatrogenic fractures appear to occur quite frequently when using traditional nails [21], especially in patients with incomplete AFF in which the femoral structure is intact. For these patients, the risk of iatrogenic fractures will be high. This problem with traditional nails is troublesome in view of the increasing number of studies revealing an association between femoral curvature and the risk of an AFF [22, 23].

In patients with preexisting joint replacement, particularly those with femoral stems in total hip arthroplasty and stemmed femoral components in total knee replacement, atypical fractures tend to occur in areas of stress concentrations at the tip of the implant [24, 25]. Moreover, the likelihood of crack propagation is high because of these stress concentrations. Because the intramedullary canal is occupied by the prosthetic stem, intramedullary fixation is impossible. Therefore, in this selected group of patients, we see the need for a preventive surgical intervention with a low risk of complications.

Lateral fixation of the incomplete atypical fracture

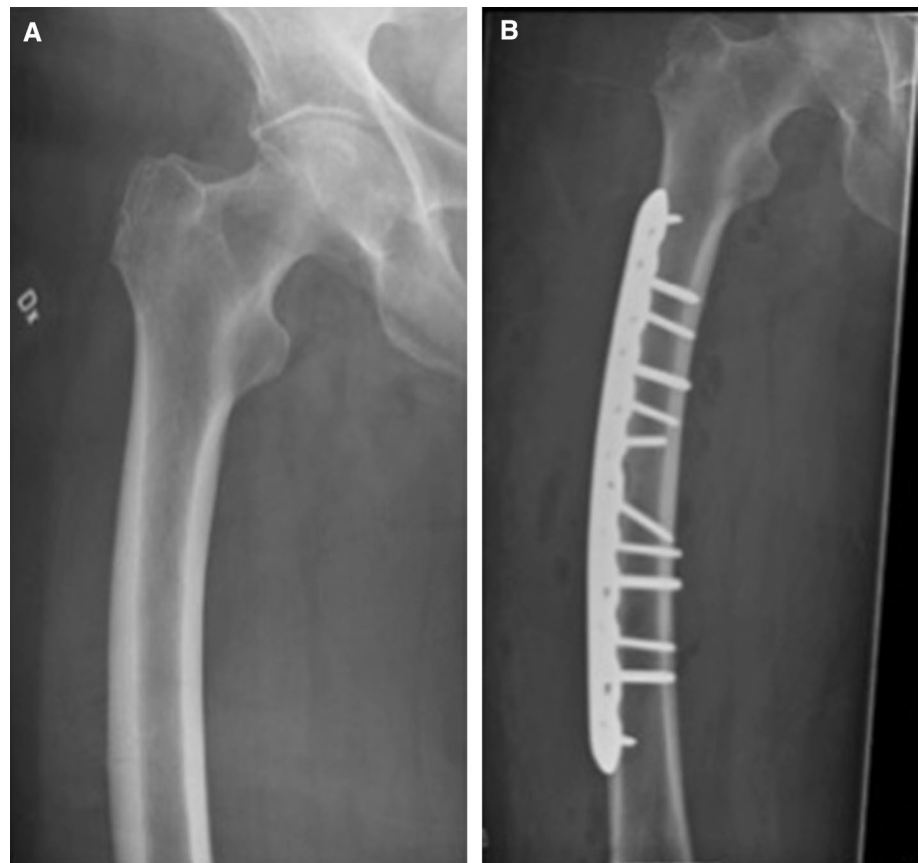
The proposed surgical intervention is based on compression and fixation of the incomplete fracture in the lateral cortex with a plate (Fig. 2b). With vertical load, such as walking, the curved femur creates a tensile force laterally and a compressive force medially [26–28]. With the plate positioned laterally, its effect is similar to a tension band preventing further widening of the crack and reducing the risk of crack propagation (Fig. 2b). We have successfully applied this approach in two patients with curved femurs (Figs. 3, 4; Table 1).

Discussion

Several authors have reported on successful conservative approaches for incomplete AFFs [29, 30]. However, recognizing that a large proportion of incomplete AFFs will progress to complete fractures without surgical fixation mandates prophylactic surgical intervention [7, 8]. Prophylactic treatment offers several benefits, including shorter operation time, reduced bleeding and shorter postoperative hospitalization [7, 31].

Lateral fixation is already a documented approach for complete AFFs, where IMNs have proven to be less effective [25]. Its use in the prevention of complete AFFs is seldom

Fig. 3 a An 80-year-old female sustained an incomplete fracture of her right femur. Before the fracture, she had received 5 years of treatment with alendronic acid because of a high dose of corticosteroids for rheumatic disease. She recalled enduring 6 months of increasing pain from her right thigh before seeking medical advice. **b** Surgery was selected as the preventive treatment of choice. Bisphosphonate treatment was discontinued before surgery. Lateral fixation was performed because of the curvature of the femur (femoral angle approximately 10°). Full weight bearing was allowed postoperatively. Radiographic examination after surgery revealed no further propagation of the fracture



reported. The current literature describes successful treatment in two patients with incomplete AFFs and significant curvature of the femurs (Table 1) [32]. Our results add further to this finding by showing that the technique is reproducible in the hands of other surgeons.

There are two main goals for the present approach. The first is to avoid a complete AFF. So far, we lack an understanding of the mechanism(s) underlying AFFs. However, accumulating evidence supports the notion that long-term bisphosphonate treatment may deteriorate the mechanical properties of the cortical bone that would lead to the formation of micro-cracks in the lateral cortex [33]. Such changes could be caused by a reduction in the mineral and matrix heterogeneity of the cortical bone, causing deterioration of tissue-level toughening mechanisms and inhibition of the mechanism of targeted remodeling [34].

Classical and more recent biomechanical analyses show that the lateral cortex of the femur is exposed to high tensile stress during each step. This stress is dependent on the activity performed and the musculoskeletal architecture of the individual [35–37]. Tensional forces at the lateral side of the bone will strive to open any existing defects (cracks) in

the cortex (Fig. 1a). These forces may favor the development of AFFs when the skeleton is exposed to bisphosphonates [23]. The importance of tensile forces is supported by the observation that atypical lesions of the femur are clustered at the region of maximal tensile loading and not at locations subjected to compressive loading [35]. Tensile forces are likely to have a greater impact in the curved femur (Fig. 2a), bringing about an increased risk of AFF [22, 23]. Lateral plate fixation might inhibit the formation of micro-cracks and the progression of an incomplete fracture.

The second goal is to enhance the possibility of healing incomplete fractures. Reduced healing capacity of incomplete AFFs can partly be explained by biomechanical factors in which daily low-impact activities are enough to cause strains that prohibit bone formation [38]. Accordingly, we believe that the healing process may benefit if this strain were significantly reduced. Both of our patients were allowed full weight bearing postoperatively and quickly recovered full walking abilities (Figs. 3b, 4b), suggesting successful healing, as reported in previous reports [32] (Table 1).

Fig. 4 a An 83-year-old female sustained an incomplete fracture of her right femur without any history of previous bisphosphonate use. She recalled having 12 months of increasing pain from her right thigh before seeking medical attention. **b** Surgery was selected as the preventive treatment. Because of the curvature of the femur (femoral angle approximately 10°), lateral fixation was performed. A biopsy of the fracture site was taken to exclude other related conditions that might have contributed to the development of a stress fracture despite femoral bow. The defect created by the biopsy showed callus formation after 3 months and complete recortication after approximately 18 months. Full weight bearing was allowed postoperatively



Table 1 Summary of available data on lateral fixation of incomplete atypical femoral fractures (four patients, five femurs)

	Age/sex	Duration of bisphosphonate use (per os)	Prodromal symptoms	Femoral curvature	Surgical treatment	Functional recovery postsurgery
Tsuchie et al., case 1	78F	4 years	Ipsilateral thigh pain for 1 month	12° (lateral) 11° (anterior)	Lateral fixation with locking plate and six bicortical screws	Able to walk without pain after 2 weeks
Tsuchie et al., case 2	77F	6 years	Bilateral thigh pain for 6 months	Right femur: 17° (lateral) 15° (anterior) Left femur: 12° (lateral) 15° (anterior)	Right femur: Lateral fixation with locking plate and six bicortical screws Left femur: Lateral fixation with locking plate and six bicortical screws	Able to walk without pain after 3 weeks
Present article, case 1	80F	5 years	Ipsilateral thigh pain for 6 months	10° (lateral)	Lateral fixation with locking plate and 10 bicortical screws	Full weight bearing postoperatively
Present article, case 2	83F	No previous bisphosphonate use	Ipsilateral thigh pain for 12 months	10° (lateral)	Lateral fixation with locking plate and eight bicortical screws	Full weight bearing postoperatively

The lateral fixation can be successfully used as a surgical preventive measure for the curved femur affected by an incomplete AFF. Further investigations are desirable before the technique can be usually applied to incomplete AFFs beyond the curved femur.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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