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Review Article

Plate osteosynthesis for atypical femoral fractures in patients with severely bowed femurs: comparing short versus long segment fixation - a case series

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Abstract: Background: Intramedullary nail fixation is currently the modality of choice in surgical treatment for atypical femoral fractures (AFF). Its uses are limited, however, in severely bowed femurs, narrow medullary canals, or in the presence of thick endosteal callus at the apex of the femoral curve. In these cases, extramedullary plate osteosynthesis is preferred. The consideration when adopting plate osteosynthesis is whether a short or long segment fixation is superior. We hypothesize that a long segment fixation has the potential advantage of protecting the entire length of the femur from future fractures in the adynamic bone. In this series, we present two cases from our institution, with the aims of discussing the benefits and limitations of short versus long segment plate fixation in AFF. Case summary: We report two uncommon cases of bisphosphonate-related AFF in two Asian patients with severe femoral curvature, who were treated with extramedullary plate osteosynthesis at our institution. One patient underwent fixation with a short segment plate osteosynthesis, and the other received a long plate osteosynthesis spanning the proximal to distal femur in an attempt to protect the bone from future fractures. Both patients showed a favourable and uncomplicated course post-surgery, with early return to ambulation and radiographic bone union at follow up. Conclusion: We expect to see an increase in the number of patients with AFF and bowed femurs, especially with the increased usage of bisphosphonates given an ageing Asian population. Surgical treatment with short and long plate osteosynthesis are options with their own advantages and limitations. With the advent of new anatomical plate options, long segment fixation has become more accessible and may be considered in this patient group as it has the potential advantage of protecting the adynamic femur from future fractures. Further studies should be targeted to determine which method of treatment is superior in this particular group of patients.

Keywords: Atypical, fracture, bowed, femurs, plate, fixation, osteosynthesis, long, short, series

Introduction

Osteoporosis is a highly prevalent chronic and progressive bone disease characterized by microarchitecture deterioration of bone tissue and reduced bone mineral density [1]. Osteoporosis is diagnosed radiographically by measuring the bone mineral density at the proximal femur and the lumbar spine using dual-energy x-ray absorptiometry (DXA) [2]. T and Z scores are calculated by comparing the bone mineral density to that of age-matched reference controls and a young adult respectively [2]. Osteoporosis is diagnosed in postmenopausal women and men older than 50 years old if their T score is less than -2.5 [2]. Osteoporosis is often referred to as a “silent disease”, as there are no clinical manifestations until a fracture occurs [3]. Hence, the significance of treating osteoporosis is the prevention of osteoporosis-related or fragility fractures, which are associated with disability, mortality, and increased healthcare costs [3]. The World Health Organization (WHO) recommends considering initiating treatment for any persons with or at risk of osteoporosis [1]. Non-pharmacological treatment includes exercise and dietary modifications, while pharmacological treatment includes a variety of antiresorptive agents [1].

Bisphosphonates are currently the mainstay pharmacological treatment for patients with osteoporosis [4]. However, long-term use of bisphosphonates has shown to be associated

Figure 1. AFF of the right femur shaft.

with an increased risk of AFF [4]. The last two decades have seen a surge in bisphosphonates usage due to the aging population, seen especially in developed countries. Coupled with an increased prevalence of femoral bowing in the Asian population [5], we expect to see an increase in the number of patients with AFF with concomitant bowed femurs. Intramedullary nail fixation is currently the modality of choice in surgical treatment for AFF [6]. However, its use is limited in severely bowed femurs, femurs with very tight medullary canals, hypoplastic femurs or in the presence of thick endosteal callus at the apex of the femoral curve. In these groups of patients, extramedullary plate osteosynthesis is a better alternative for surgical treatment.

Conventionally, extramedullary plate osteosynthesis is performed with a plate spanning across the fracture, which we consider short segment fixation. However, the use of long segment fixation, with plates that span across the entire femur, has been described to have further advantages to protect the femur from future fractures. To our understanding, there are currently no studies comparing the outcomes of short versus long segment fixation in plate osteosynthesis of AFF, and no consensus as to which is superior. In this series, we present two cases of bisphosphonate-related AFF in two Asian patients with severe femoral curvature, and explore the benefits and limitations of using short versus long segment plating for fixation of AFF.

Informed consent was obtained from all patients for participation in this case series.

Case 1

A 72-year-old woman presented to our institution in August 2017 after sustaining a right AFF and underwent short segment plate fixation.

Her past medical history was significant for osteoporosis for which she was treated with alendronate for 3 years. She was independent in her activities of daily living and ambulant in the community without walking aids. The patient fell at home after losing her balance. Prior to her fall, she complained of bilateral thigh pain for an estimated duration of 6 months.

Radiographs revealed an atypical fracture of her right femoral shaft, demonstrating a transverse fracture pattern with a medial spike, lateral cortex thickening and lack of comminution (**Figure 1**). There was also an incomplete atypical fracture of her left femoral shaft, with a transverse fracture line at the lateral cortex and presence of lateral cortex periosteal thickening at the fracture site (**Figure 2**). Both femurs demonstrated an exaggerated bow anterolaterally. In accordance with the American Society for Bone and Mineral Research (ASBMR) case definition, both femurs fulfilled the criteria for the diagnosis of AFF.

The patient was counselled for surgical fixation of her right femur. Preoperative templating using her left femur ruled out the possibility of intramedullary nailing due to the severe femoral bow, hence she was planned for surgical fixation with a plate osteosynthesis. Surgery was performed under general anaesthesia, with the patient in a left lateral decubitus position on a radiolucent table. The fracture site was opened via the direct laterally approach with elevation of the vastus lateralis. After reduction was achieved, a 12-hole plate (DePuy Synthes LCP® 4.5 broad locking compression plate system) was contoured and applied on the lateral surface of the femur (**Figure 3**).

Postoperatively, the patient recovered uneventfully, and she underwent prophylactic fixation of her left femur 7 days later. The direct lateral approach was adopted again and the fixation was performed using a minimally invasive sub-

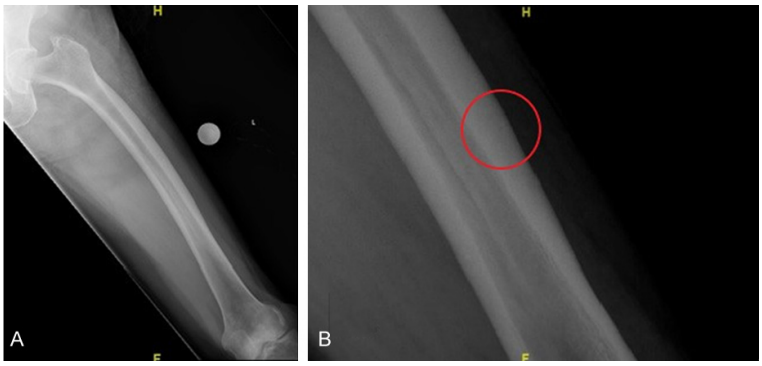

Figure 2. Anteroposterior radiographs of left femur, demonstrating (A) severe anterolateral bowing of femur and (B) incomplete atypical femoral fracture of lateral cortex with cortical reaction and transverse fracture line (circled).

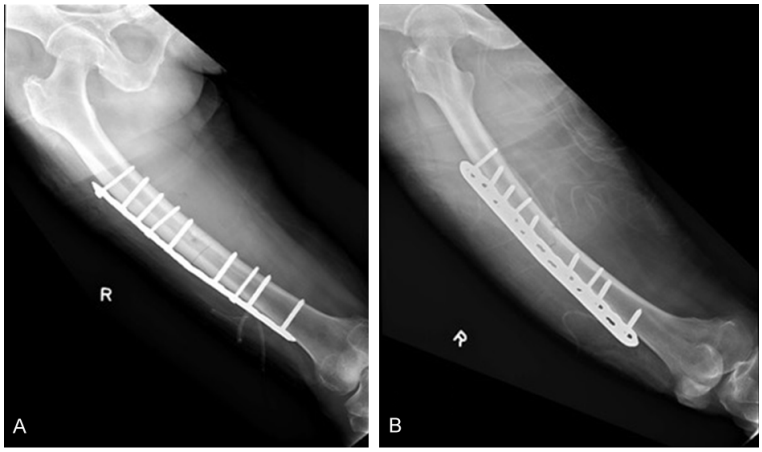

Figure 3. (A) AP and (B) lateral radiographs of right AFF post extramedullary plate osteosynthesis with restoration of femoral bow.

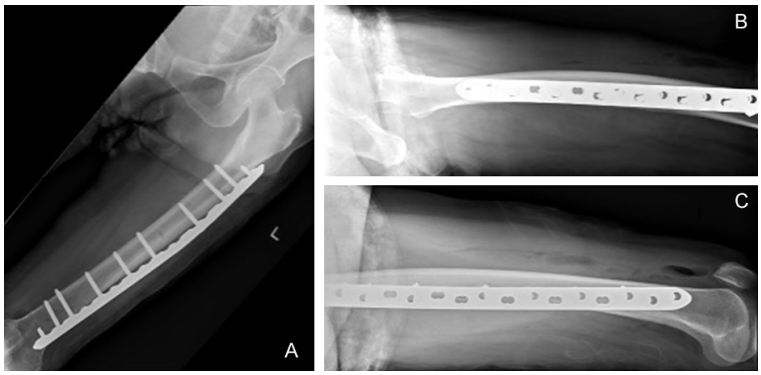

Figure 4. (A) AP and (B), (C) Lateral radiographs showing prophylactic extramedullary plate osteosynthesis of left femur.

muscular technique. A longer 18-hole plate (DePuy Synthes LCP® 4.5 broad locking compression plate system) was used, spanning from the subtrochanteric region to the supracondylar region (**Figure 4**). The patient was allowed partial weightbearing on her left lower limb but non-weightbearing on her right lower limb with a walking frame. She recovered uneventfully and was discharged to the community hospital for rehabilitation. She was last seen in the specialist outpatient clinic at 9 months postoperatively. Radiographs showed evidence of fracture union (**Figure 5**) and she was ambulating independently with a walking frame.

Case 2

A 76-year-old woman presented to our institution in January 2020 after sustaining a left AFF and underwent long segment plate fixation.

Her past medical history was significant for osteoporosis for which she was treated with alendronate for 30 months. She was independent in her activities of daily living and ambulant in the community without walking aids. She slipped and fell at home and landed on the left side of her body. Prior to the fall, she complained of prodromal left thigh pain for 12 months, and right thigh pain for 4 months.

Radiographs revealed an atypical fracture of the left femoral shaft, demonstrating a short oblique fracture pattern, lateral cortical thickening and lack of comminution (**Figure 6**). There was no fracture or "dreaded black line" on the right femur, although extensive periosteal reaction was seen over the lateral cortex at the junction of the middle and distal shaft (**Figure 7**). Similar to case 1, both femurs demonstrated an exaggerated

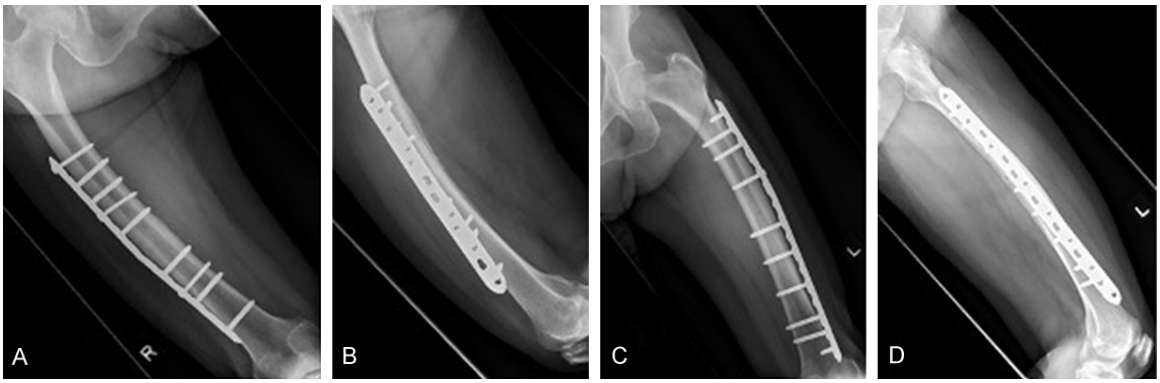

Figure 5. Extramedullary plate osteosynthesis of right and left femurs 9 months post fixation, showing right femur (A) AP and (B) lateral radiographs, left femur (C) AP and (D) lateral radiographs.

Figure 6. (A, B) AP and (C, D) lateral radiographs showing AFF of the left femur shaft.

bow anterolaterally. Magnetic resonance imaging (MRI) of the right femur (**Figure 8**) was performed, which showed periosteal reaction and oedema over the distal femur shaft, suggestive of an ongoing stress injury. The abovementioned findings fulfilled the criteria for the diagnosis of AFF according to the ASBMR definition.

The patient was counselled for surgical fixation of her left femur. Similarly, due to the severe femur bow, she was planned for surgical fixation with a plate osteosynthesis. Surgery was performed with the patient supine. 2 Schanz pins were inserted anteriorly on each side of the fracture to aid reduction (and subsequent compression at the fracture ends) and the fracture site was opened direct laterally with elevation of the vastus lateralis. After achieving adequate reduction, a long plate (Zimmer NCB® Periprosthetic Femur System) was contoured and tunnelled submuscularly, on the lateral surface of the femur. The choice of implant was due to the many available screw hole options. This proved to be particularly useful given the excessive bow of the femur, where the plate cannot be contoured perfectly to fit the bone. The implant also allows for placement of screws into the femoral head and neck, potentially conferring additional protection from a subsequent fracture in the proximal femur (**Figure 9**).

The patient's recovery in the ward was uneventful postoperatively, and she underwent prophy-

Figure 7. (A) AP and (B) lateral radiographs showing endosteal and lateral cortical reaction in right femur shaft with severe bow.

lactic fixation of her right femur 4 days later. The plate was similarly contoured as per her left side. The direct lateral approach was adopted, and the fixation was performed using a minimally invasive submuscular technique. Again, an identical plate was used, and screws spanned proximally from the femoral head-neck to the supracondylar region (**Figure 10**). The patient was allowed to full weight bear on her right lower limb but non weight bear on the left lower limb with crutches for 8 weeks. She recovered uneventfully and was discharged to the community hospital for rehabilitation 6 days after the second surgery. She was last reviewed in the outpatient clinics at 15 weeks postoperatively. Radiographs showed evidence of fracture healing (**Figure 11**) on the left. She was ambulating independently during her last review.

Discussion

AFF occur uncommonly with a reported incidence of only 50 to 130 cases per 100000 patient-years [6]. Although it has been mainly reported to be associated with bisphosphonate therapy, AFF can occur in other conditions such as non-Hodgkin's lymphoma, vitamin D deficiency, rheumatoid arthritis and various bone

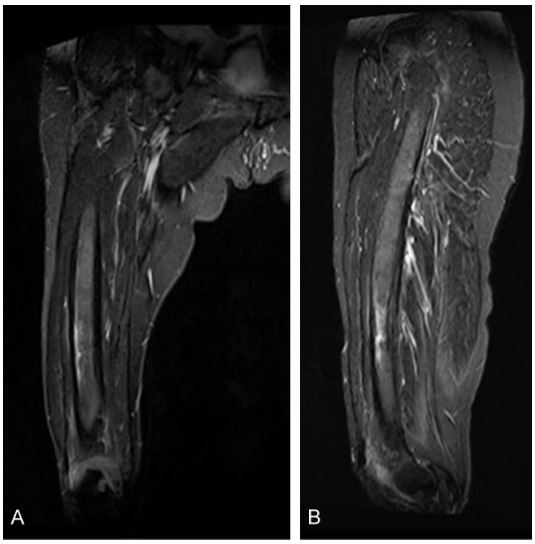

Figure 8. (A) Coronal and (B) sagittal MRI images showing bony oedema and periosteal-medullary inflammation of right femoral shaft suggestive of ongoing stress injury.

diseases such as osteopetrosis [7]. The ASBMR defines AFF as a fracture located along the femoral diaphysis from just distal to the lesser trochanter to just proximal to the supracondylar flare. It should occur with minimal to no trauma. Radiologically, the fractures should be noncomminuted or minimally comminuted, with a transverse or short oblique fracture orientation at the lateral cortex, and a medial cortex spike additionally in a complete fracture [8]. The pathogenesis of AFF suggests that these are stress or insufficiency fractures [9]. The mechanisms proposed are firstly, over-suppression of bone turnover leading to accumulation of microdamage, secondly, the inhibition of bone remodelling resulting in reduced heterogeneity of the bone matrix and hence increasing stress locally and susceptibility to crack formation, and thirdly, alterations in extracellular collagen cross-linking leading to reduced energy requirements for fracture occurrence [9].

Patients with complete or incomplete AFF are generally recommended to undergo surgery in the form of either intramedullary nailing or extramedullary plate osteosynthesis [7]. Conservative treatment such as limiting weight-bearing and starting bone-forming agents should only be applied in patients with painless incomplete fractures or who are medically unfit for surgery [10]. Intramedullary nailing is the

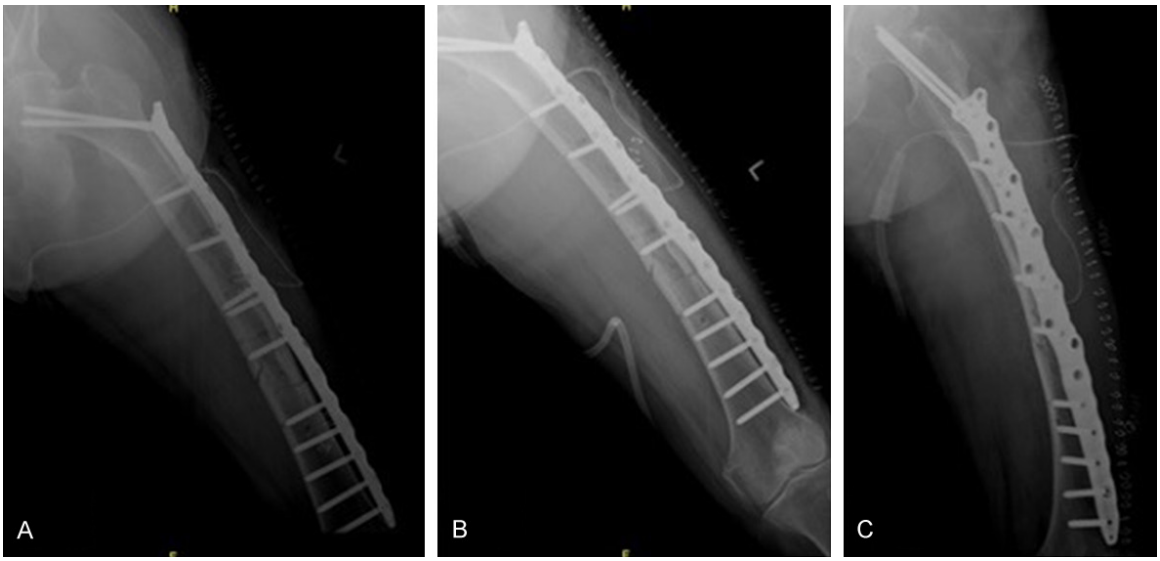

Figure 9. (A, B) AP and (C) lateral radiographs showing left AFF post extramedullary plate osteosynthesis with restoration of femoral bow.

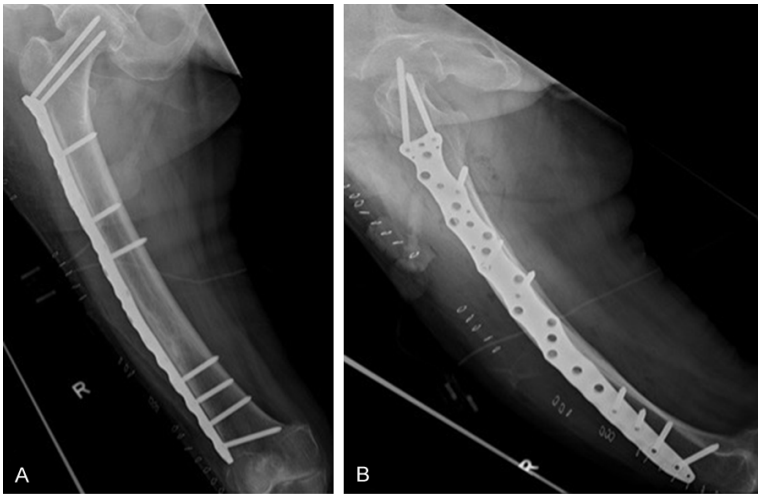

Figure 10. (A) AP and (B) lateral radiographs showing prophylactic extramedullary plate osteosynthesis of right femur.

modality of choice for internal fixation currently [6, 11], as it is believed to be superior to extramedullary plate osteosynthesis both biologically and biomechanically. Biologically, extramedullary plate osteosynthesis precludes endochondral ossification, and coupled with impaired osteoclast remodelling from bisphosphonate therapy [10, 12], there is impaired fracture healing [13]. Biomechanically, intramedullary nailing is believed to provide greater load distribution and better resists bending movements at the fracture site compared to extramedullary plate osteosynthesis [14].

However, extramedullary plate osteosynthesis is still employed in cases where intramedullary nailing is difficult. In patients with severe anterolateral bowing of the femur, such as in both of our cases, intramedullary nailing poses a danger of iatrogenic perforation of the femoral cortex. Furthermore, there is a danger of inadvertently straightening the femur post nailing, resulting in a limb length discrepancy [15, 16]. Intramedullary nailing is also difficult if the medullary canal is too narrow [17], or when there is presence of thick endosteal callus at the apex of the femoral curve [18]. In hypoplastic femurs, nailing may not be possible.

In both our patients, preoperative templating using a dedicated TraumaCad® software had ruled out the possibility of intramedullary nailing due to the severe anterolateral bowing of the femurs. Hence, the decision was made to proceed with extramedullary plate osteosynthesis in both cases.

The Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation currently recommends

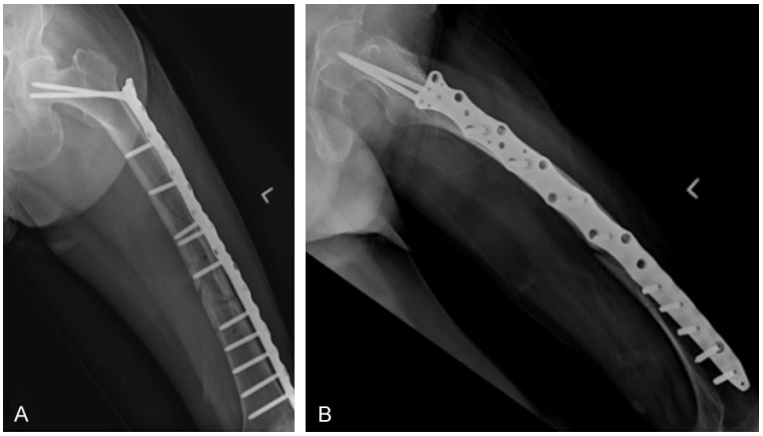

Figure 11. (A) AP and (B) lateral radiographs showing left AFF 15 weeks post fixation.

the insertion of at least three bicortical screws into each fracture fragment for compression plating of transverse fractures of the femoral midshaft, and a minimum of three up to six bicortical screws into each fracture fragment when utilizing the bridge plating technique [19]. With regards to ideal plate length, a plate span ratio (total plate length divided by overall fracture length) of 2-3 for comminuted fractures and 8-10 for simple fractures has been described [20, 21]. Utilizing the principles above, this usually results in a short segment plate fixation based on the fracture configuration in an AFF. This is represented by our patient in Case 1, who underwent a short segment plate fixation with a locking compression plate (LCP) of her right AFF.

When our patient in Case 2 presented to our hospital after sustaining an AFF, we immediately noticed the similarities with case 1. Both patients had a history of bisphosphonate use, and both had severely bowed femurs requiring fixation with extramedullary plate osteosynthesis. With the advent of newer anatomical plates, we elected to perform long segment plating to span the proximal to distal femoral shaft including the femoral head-neck region, so as to confer protection to the relatively adynamic bone and to prevent against a future reoccurrence of the fracture which would further complicate management. We chose to protect the femoral head-neck rather than a distally based plate as we believe that the subsequent surgical management of a distal based fracture will be easier to perform should a fracture occur below the level of the plate. We then performed long segment prophylactic fixation of the contralateral femur.

As extramedullary plate osteosynthesis is not the mainstay of surgical treatment of AFF, there is a paucity of literature comparing short versus long segment fixation of AFF. There is also no consensus with regards to short versus long segment fixation of these fractures when plate osteosynthesis is being utilized, although we believe that long segment plate fixation is used less frequently as there is scant description in the literature. Therefore, we decided to showcase these cases to highlight the benefits and limitations of short versus long segment plate fixation of AFF.

Long segment plating from the femoral head-neck to the distal femur was applied in case 2 with the aim of prophylactic prevention of future fractures in view of existing risk factors for AFF. The effects of bisphosphonates are known to persist despite ceasing treatment due to their strong bond to hydroxyapatite on the surface of bone [22]. Although studies have reported a reduction in risk of a second AFF after bisphosphonate therapy is ceased following the first [22], the current data is not robust. It is also important to note that the consequences of a second AFF along the same femur will lead to a poorer outcome, with more complications and higher mortality rates described [6]. A study by Lee et al has described and recommended for whole bone plating of AFF, covering the full length of the femur, to avoid refracture of the femur in situations where intramedullary nailing is difficult, although patient outcomes were not reported [17]. Won et al also reported satisfactory outcomes in 2 cases of precontoured plate fixation spanning the whole femur for incomplete AFF with severely bowed femurs [23]. Another study by Moloney et al comparing the use of short and long plates in periprosthetic femur fractures after hip arthroplasty also found that long plates protecting the length of the femur up to the level of the femoral condyles had a lower refracture rate [24].

In comparison, fixation of AFF with a short segment plate can concentrate stress at the ends of the plate, due to differential stiffness at the plate-bone junction, as described in a study by Lee et al [24]. The authors noted that the areas under stress become more susceptible to chronic stress reactions, and subsequently progress to peri-implant fractures. Additionally, the risks of peri-implant fractures are further increased if the short plate ends in a region where tensile stress is high, such as the subtrochanteric area, or where there is maximum bowing of the femur shaft. Hence, the use of a longer plate that ends in the lower metaphyseal region is recommended, as it reduces the risks of peri-implant fractures sustained from the use of a short segment plate [25].

Additionally, from a biomechanical standpoint, the use of longer plates is thought to decrease plate loading, thereby reducing the risk of fatigue failure by minimizing cyclic loading [20]. A longer plate with more empty screw holes at the fracture site offers a longer working length, achieving a larger area of stress distribution on the plate at the level of the fracture, which confers better resistance against fatigue and aids fracture healing when compared to a short plate [21, 26].

On the other hand, there are potential disadvantages to long segment plating. Firstly, in order to attach a plate along the entire length of the femur, a significant amount of periosteum needs to be stripped. Periosteal stripping results in the removal of the cambial layer containing osteoprogenitor cells, impairing the regeneration of bone and fracture healing [27, 28]. An animal study has shown that cortical bone perfusion was significantly reduced after periosteal stripping was performed over the whole length of the tibia in sheep [29]. Hence, the use of long plates theoretically increases the risk of bony nonunion in AFF and subsequent fatigue failure of the plate. Secondly, the use of a longer plate necessitates a longer skin incision as well as a larger region of soft tissue manipulation for visualization of the fracture site. This translates to an increased surgery time with increased anaesthetic risks, more intraoperative blood loss, and increased risks of infection for the patient [30, 31]. Hence, there is a move towards minimally invasive plate osteosynthesis (MIPO) in recent years to mitigate these risks [32]. However, this is more technically demanding and has a steep learning curve. Even with the use of anatomical plates, much contouring is still required due to the excessive femoral bows in these patients, making MIPO plating even more challenging.

In comparison, short segment plating requires less periosteal stripping, preserving the vascularity of the bone. Increasing age has been described to negatively affect the different stages of bone fracture healing, in part due to the decrease in vascular perfusion of the skeleton with age [33]. An argument can hence be made for short segment plating in patients who are more elderly [34]. Furthermore, short segment plating allows for a shorter skin incision with less tissue dissection, shorter operative time, and less intraoperative blood loss [24]. This can be beneficial for frail patients with other medical conditions which predispose them to higher risks of anaesthesia and surgery.

As bisphosphonates become a mainstay therapy for osteoporosis, we expect an increase in the number of cases that present similarly to the 2 patients in our report, especially with the increased prevalence of femoral bowing in the Asian population [5]. Although short segment plating is adequate for primary fixation of AFF, long segment plate fixation spanning the whole femur may be considered as prophylaxis against future fractures. The advent of new anatomical plates in a variety of precontoured and screw hole options also further increases the accessibility of long segment plating in this patient group. Future studies should be targeted to determine which method of treatment is superior in this particular group of patients.

Conclusion

We expect to see an increase in number of patients with AFF and bowed femurs, especially in the Asian population. Surgical treatment with short and long plate osteosynthesis are options with their own advantages and limitations. With the advent of new anatomical plate options, long segment fixation has become more accessible and may be considered in this patient group as it has the potential advantage of protecting the adynamic femur from future fractures. Further studies should be targeted to determine which method of treatment is superior in this particular group of patients.

Disclosure of conflict of interest

None.

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