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ORIGINAL ARTICLE • LOWER LIMB - FRACTURES

# Early versus delayed weight bearing after surgical fixation of distal femur fractures: a non-randomized comparative study

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## Abstract

Distal femur fractures are rare injuries with a bimodal distribution (high-energy injury in young males and low-energy fragility fractures in old females). Their management can be challenging: open reduction and internal fixation (ORIF) with distal femur locking plates is a commonly performed procedure especially in comminuted fractures with articular involvement. Anxiety regarding the stability of the fixation, especially in osteoporotic bone, leads to post-operative restrictive instructions with limitations regarding the weight-bearing status. Early weight bearing (EWB), however, was shown to enhance bone healing and was not correlated with an increased risk of fracture displacement or implant failure in previous published studies, which reported the results of proximal femur, tibia and ankle fractures surgical treatment. The current study analysed the results of a series of distal femur fractures (51 patients, mean age 64.3 ± 20.7) all treated with ORIF in a level-I major trauma centre, but differently rehabilitated. Group A was, in fact, instructed not to weight bear or to touch weight bear, while group B started to weight bear soon after surgery without specific restrictions. The objective was to compare the outcome and the complication rate in the two groups at 6 and 12 weeks after surgery. The results showed no statistically significant differences in the two groups and no post-operative complications in the EWB group. Six complications were observed in the non-weight-bearing group (four fractures displacement and two implants failure at 12-week follow-up). Distal femur fractures treated with locking plates can be rehabilitated with EWB to allow early return to function. There is no evidence that EWB increases the risk of fracture displacement or implant failure in distal femur fractures treated with distal locking plates. Instead, it is possible that post-operative non-weight-bearing status delays the fracture-healing process increasing the risk of failure of the fixation.


**Keywords** Fracture healing · Femur fracture · Callus · Weight bearing · Rehabilitation

## Introduction

Distal femur fractures account for 3–6% of femoral fractures in adults and 0.4% of all fractures [1]. They are more frequent in young men (high-energy trauma) and elderly females whom often sustain low-energy injury, such as a fall from standing.

The management of these fractures can be challenging, and complications following fracture fixation have been reported to be between 2 and 10% for non-union and implant failure, between 4 and 40% for malunion, and reoperation rates between 3 and 23% [2]. The mortality rate can be as high as 30% within the first year after surgery.

Achieving stable fixation of distal femoral fractures is a challenge: lateral locking plates have been used routinely in distal femoral fractures since they were introduced in the 1990s [3]. The ability to lock the screw head in the plate provides a fixed angle device and allows the load to be spread uniformly at the bone–implant interface; the different orientation of the screws increases the hold in the cancellous metaphyseal bone of the distal femur, reducing the risk of pull-out of the screws [4]. In osteoporotic bone, the

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decreased mineral density affects the holding capacity of screws [5] decreasing significantly the pull-out strength, so the stability of the construct. Furthermore, these new systems allowed to bridge metaphyseal comminuted fractures using minimally invasive technique (without violation of bone-preserving blood supply [6]), aiming to regain length, restore the axis, and the correct rotation, intending to generate relative stability, which was shown to reduce the strain at the bone–implant interface. However, despite good initial outcome [7], once the indications were extended to different fracture types (complex articular or comminuted fractures) and to a larger number of patients (with risk factors for delayed union and non-union), the fatigue failure rate started to raise up and was reported to be as high as 32% [8].

To overcome this problem, retrograde intramedullary nails, or adaptations of techniques such as dual plating, or adjunctive fixations, have been utilized to add stability and avoid implant failure (especially varus collapse in comminuted metaphyseal fractures) [9, 10]. Despite modern implants and fixation techniques, early weight bearing (EWB) after fixation of distal femoral fracture is usually restricted based on the fear of early failure of the fixation. The load transmitted to the bone–implant interface can often be relatively too high, especially in mal-reduced fractures and osteoporotic bone and can lead to microfractures, resorption, and loosening of the implant. Consequently, partial weight-bearing (PWB) or non-weight-bearing (NWB) instructions are usually given to patients whom undergo surgical fixation of distal femur fracture with plate and screws.

Both bone modelling/remodelling and mass density are directly linked with direct load bearing and, at the fracture site, in a biologically favourable environment where sufficient blood supply is guaranteed, the healing process is enhanced by micromovements of bone fragments [11–13] and by the fracture stability. Local mechanical factors at the fracture site influence cell differentiation and phenotype: sites of small-to-moderate strain benefit osteoblastic differentiation, whereas larger strains increase the proportion of fibroblastic cells and the likelihood of fibrous union [14, 15]. Also in osteoporotic bone, the fracture-healing process is not different although it takes longer. Early ambulation and weight bearing as tolerated (WBAT) for proximal femur fractures were associated with accelerated recovery resulting in shorter acute care length of stay and increased probability of being discharged directly home and reduced mortality.

Currently, there are no existing guidelines or consensus on the treatment and management of complex distal femoral fractures, nor on the post-operative treatment regarding safe weight bearing in order to reduce morbidity and mortality rates [16].

This study analyses the results of two groups of patients surgically treated for distal femur fractures with respect to their rehabilitation protocol and post-operative instructions: those instructed to weight bear without restriction versus those treated with limited or no weight bearing in the post-operative period. The objective of the study is to evaluate the outcome and complication rate between the two groups. The hypothesis is that there are no differences in the two groups as distal femur fracture fixations can tolerate EWB with early return to function and without an increase in the complications observed.

## Methods

A retrospective analysis of our prospectively collected trauma database was performed: between January 2014 and May 2017, 70 consecutive patients treated for distal femoral fracture at our level-I major trauma centre were identified. Patients who were treated with fixation using plate(s) and screws were included to the study. Surgery was performed by surgeons who decided the surgical technique to use at their discretion. Locked screws were typically used in the metaphysis if appropriate. Non-locked screws were generally utilized in the diaphysis. The number and position of plates were according to fracture pattern. Either cancellous or synthetic bone graft was used in any of the operations [17]. All the intra-operative images obtained with the image intensifier were saved to our IntelliSpace Picture Archiving and Communication System (PACS) system.

Patients treated with acute knee arthroplasty following distal femoral fractures were excluded, as were those treated non-operatively, or with retrograde nailing, screw fixation in isolation or external fixation. Demographic, injury, operation and radiological data were collected. The weight-bearing status of the patients immediately after the operation was retrieved from the operation notes of the patients.

We categorized patients into two groups according to the post-operative weight-bearing status. Group A consisted of delayed weight-bearing (DWB) group, which includes patients instructed not to weight bear (NWB) and to toe touch weight bear (TTWB) (the foot or toes may touch the floor to maintain balance, but not support any weight), and group B consisted of early weight-bearing (EWB) group, which includes patients instructed to partially weight bear (PWB > 50% body weight), weight bear as tolerated (WBAT) and fully weight bear (FWB). The post-operative protocol and instructions were decided by the operating surgeon.

All the patients were transferred to an orthopaedic ward for post-operative care—all were seen by the physiotherapy team the first day post-operatively and started the rehabilitation accordingly. Continue passive motion (CPM) machine was not used in any case. An X-ray (antero-posterior and lateral views) of the distal femur was performed in all the patients within the first two post-operative days. Once clinically safe, the patients were either discharged home or to a rehabilitation centre depending on the level of autonomy reached during the hospital stay.

Clinical and radiological assessments were performed in all the patients in specialized complex trauma clinics at 6 and 12 weeks post-operatively. All the patients were seen by the operating surgeons or fellows, or by a senior trainee. For this study, all radiographs (antero-posterior and lateral views of the distal femur) were reviewed by two independent doctors and then compared. Radiographs were analysed using the PACS Enterprise Version 4.4.516.15 with magnification 115%.

All the follow-up images were compared with the immediate post-operative X-rays. The position of the implants was recorded, and signs of fatigue failure (implant failure, resorption and loosening) were evaluated by two independent examiners (EI, TA). The articular surface reduction was evaluated and considered displaced if a change of more that 1 mm was observed, compared to the post-operative X-rays (factoring for radiograph magnification). Varus and valgus deformities were examined by measuring the mechanical axis of the femur from the centre of the femoral head to the centre of the femoral notch. When an all-femur X-ray was missing, the anatomical axis of the femur was used to determine the axis.

Statistical analysis was performed using the statistical program SPSS ver.23, and the statistical significance was set to 0.05.

## Results

Fifty-one out of 70 patients were included in this study. The mean age of the cohort was 64.3 ± 20.7 years with the majority of the patients being female (63%). Most of the patients (40%) had a complete articular distal femoral fracture, AO Type 33C. Thirty-nine patients (76%) were treated with one lateral distal femoral plate. The total number of the patients in group 1 was 32 (63%) with 19 patients (37%) in group 2. The mean age of the two groups was 61.1 ± 21.1 and 63.7 ± 17.4, respectively. Table 1 summarizes the cohort demographics and descriptors.

The weight-bearing status did not correlate with the fracture type or the fixation type ($p > 0.05$). None of the patients had fracture displacement at 6 weeks (Table 2), with displacement defined as fracture loss of reduction ≥ 1 mm. Four of the patients from the NWB group had displacement at the fracture site at the 3-month follow-up radiographs (Table 3). Fisher's exact test revealed no statistically significant difference between the two study groups at both follow-up time points ($p = 0.55$). Two of the patients in the NWB group had their plate broken at the 3-month follow-up and required revision fixation. In the EWB group, no patients were found to have fracture displacement or implant failure at any time in the study.

**Table 1** Cohort study features: gender, type of injury and operation

| Data | Group A (%) | Group B (%) | *p* value |
|---|---|---|---|
| Gender | | | 0.518 |
| Male | 13 (40.6) | 6 (31.6) | |
| Female | 19 (59.4) | 13 (68.4) | |
| Type of injury | | | 0.947 |
| 33A | 9 (17.7) | 4 (7.9) | |
| 33B | 2 (3.9) | 1 (1.3) | |
| 33C | 12 (23.6) | 8 (15.8) | |
| Periprosthetic | 9 (17.9) | 6 (11.9) | |
| Type of operation | | | 0.883 |
| Lateral plate | 25 (49.2) | 14 (27.7) | |
| Lateral and medial plate | 5 (9.9) | 4 (7.9) | |
| Medial plate | 2 (3.9) | 1 (1.3) | |
| Weight-bearing status | 32 (62.7) | 19 (37.3) | |

## Discussion

Wolff [18] described the ability of skeletal tissue to remodel and alter its architecture in response to the mechanical forces acting on it. Under normal physiological conditions, the strain in bone is at a level where it is in homeostasis, with a slow turnover of bone resulting from balanced osteoblast and osteoclast function [13]. Animal osteotomy models have shown that controlled or moderate axial loading of the osteotomy site typically leads to a greater volume of callus [11] and a faster time to union compared with no loading or excessive early loading. While high strains impede bone formation, moderate uniaxial strains between 0.3 and 2.8% stimulate in vitro osteoblast activity, including proliferation and synthesis [19]. In fractures, the strain is initially high and granulation tissue and fibrous callus formation is

**Table 2** Results at 6 weeks of follow-up

| Displacement (6 weeks) | None | > 1 mm |
|---|---|---|
| Non-weight bearing | 32 | 0 |
| Weight bearing | 13 | 0 |

**Table 3** Results at 3 months of follow-up

| Displacement (3 months) | None | > 1 mm |
|---|---|---|
| Non-weight bearing | 26[a] | 4 |
| Weight bearing | 13 | 0 |

[a]Two patients in the non-weight-bearing group had their plate broken at the 3-month follow-up and required revision fixation

observed; the fracture site becomes gradually stiffer until the strain is low enough for the bone to form.

There is evidence that the bone reacts to external mechanical stimuli as loading and weight bearing. Also at the level of a fracture, the bone physiologically reacts to these stimuli improving its potential to heal. In osteoporotic bone, the fracture-healing process is not different although it takes longer [20]. Both bone modelling/remodelling and mass density are directly linked with direct load bearing and, at the fracture site, in a biologically favourable environment where sufficient blood supply is guaranteed, the healing process is enhanced by micromovements of bone fragments [11–13] and by fracture stability. Local mechanical factors at the fracture site influence cell differentiation and phenotype: sites of small-to-moderate strain benefit osteoblastic differentiation, whereas larger strains increase the proportion of fibroblastic cells and the likelihood of fibrous union [14, 15].

Post-operative weight-bearing protocols should be hence focused on early mobilization and return to function to optimize fracture healing while avoiding fracture displacement or implant failure.

However, there is little evidence in the clinical practice that EWB is safe and that surgeons should recommend early mobilization to all patients (especially elderly patients).

Evidence is provided for rehabilitation of patients with hip fractures, as it has pioneered accelerated rehabilitation protocols and early discharge. Early ambulation and WBAT for proximal femur fractures were associated with accelerated recovery resulting in shorter acute care length of stay and increased probability of being discharged directly home and reduced mortality [21]. The aim of treatment should be to return the patient to independent living, but, among the elderly population, only 58.4% of very elderly patients who had previously lived independently were able to return to their original address. These considerations have a vast economic implication and will create a major burden on medical resources in the next years as the elderly population is predicted to consistently increase in the next decades.

Garden et al. [22] encouraged immediate weight bearing after proximal femoral fracture fixation in the elderly; later, many other authors [23–25] supported the idea of early mobilization and weight bearing in this group of patients, showing good results. Their recommendations gained considerable support in the literature, and early rehabilitation is now widely accepted as the standard of care for this type of fracture.

Another study [26] supported the importance of early mobilization and recovery of ROM in distal femoral fractures, particularly when the articular surface is involved. However, the authors recommended TTWB for 10–12 weeks for all the complex 33-C2 and 33-C3 fractures. Unfortunately, there is no information regarding the post-operative weight-bearing status for fracture type 33-A and 33-B. A recent multicentre study [16] analysed the outcome of 105 patients treated for distal femur fractures (both with locking plates and with intramedullary nails) in four level-I major trauma centres: the majority of the patients (69%) were mobilized NWB or TTWB after surgery, and only a minority (14%) were instructed to fully weight bear. Despite that the majority of the patients were protected post-operatively, the authors supported the importance of early rehabilitation and reported that they did not observe an increase in peri-operative complications in the EWB group. They concluded that distal femur fractures should be rehabilitated like proximal femur fractures, so with early mobilization and weight bearing.

Similar considerations can be discussed for other lower limb injuries. The effect of EWB in tibial plateau fractures was previously observed in our unit (2018) analysing the results of 90 patients treated with ORIF [17]. One group was allowed to weight bear as tolerated from day 1 post-operatively, and the control group was instructed to TTWB or NWB for 6 weeks. The study showed that EWB did not increase the complication rate and did not compromise the fixation or the reduction of the articular surface at 3-month follow-up [17]. Also KT Haak et al. [27] compared EWB and delay weight bearing after ORIF of tibial plateau fractures (limited to AO type 41B). They did not show an increased risk of failure and displacement of the fracture in the EWB group at 6–8-week follow-up. However, they only used locking plates in their series, and they retrospectively studied a small number of patients. Other studies [28–30] compared tibia plateau fracture fixation post-operative rehabilitation, but none of them allowed unrestricted weight bearing after surgery allowing only 10–20 kg of PWB, and therefore, the results have to be prudently analysed.

Also, the effects of EWB after ankle fracture ORIF have been investigated: a Cochrane meta-analysis of early versus late weight bearing after ankle fractures showed no difference between groups in ROM, functional scores, or radiographic outcomes, 1 year after injury. This analysis was based on three studies that directly compared early and late weight bearing after ankle fractures without other confounding variables; all three studies were published before 1990 [14, 31]. Van Laarhoven et al. [32] randomized 81 patients, whom underwent ankle fracture ORIF, either to EWB or DWB (after 6 weeks); both groups were initially treated for 2–5 days in plaster cast. Better functional scores were observed in the first days (10 days) and weeks (6 weeks) in the EWB group; no differences were appreciated at 3- and 12-month follow-up. Dehghan et al. [33] randomized 110 ankle fractures aiming to compare EWB and ROM to NWB and immobilization in a cast after surgical fixation of unstable ankle fractures; all the patients were kept in a back slab for 2 weeks post-operatively. The EWB group gained ankle ROM faster and showed better outcome and less post-operative complication rate (2% vs 29%); however, no difference was seen in the rate of return to work. Also Simanski et al. (2006) reported quicker recovery and better ROM in patients with ankle fractures treated with ORIF and EWB compared to a controlled group of patients treated with plaster cast and immobilization with NWB status for 6 weeks [34]. Gul et al. [35] showed no difference in terms of hardware failure and reoperation rate treating Weber A, B and C ankle fractures with ORIF and either NWB status in plaster cast for 6 weeks or EWB without protection post-operatively. The EWB group had a faster return to function and did not have disadvantages concerning hospital stay, pain intensities and functional scores [35].

So not only does weight bearing stimulate fracture healing, non-weight bearing can indeed be detrimental. Prolonged immobilization can cause physiological changes in the human body: the consequences of 10 days of bed rest in healthy adults lead to substantial loss of lower extremity strength, power and aerobic capacity and a reduction in physical activity. Older individuals treated with immobilization have increased risk of deep venous thrombosis (DVT) and pulmonary embolisms (PEs), pneumonia, cardiovascular diseases [36], pressure sources and infection. Clement et al. [37] showed a significantly increased mortality risk for very elderly (> 90 years of age) patients with lower limb fractures in whom surgery is delayed (> 48 h), and they highlighted the need for early mobilization to reduce the possible risk related to prolonged bed rest and hospital stay.

Furthermore, should one chose to manage a patient with restricted weight bearing, it is common that there will be issues with the compliance of certain patients' categories (i.e. patients with learning disabilities or associated injuries, alcoholics, drug abusers, elderly patients, etc.) who are instructed to partially or non-weightbear. The problem can be related to intrinsic muscular weakness, poor upper body strength, poor compliance, dementia and post-operative delirium, lack of training methodology and difficulty in judging pressure over the lower extremities. Patients usually tend to exceed target loads by 50% or more even after specific training with continuous auditory feedback due to the time lag between auditory perception and motor response and the rapid rate of loading of the extremity. Instruction to NWB can also be criticized as they are seen to be related to a higher risk of accidental fall post-operatively [14, 15].

The right balance between EWB and DWB in distal femoral fracture fixations has not been found yet and most of the time the fear of allowing patients to early weight bear after surgical fixation, prevails. Prolonged immobilization and NWB instructions have been always considered as the safest options after distal femur surgical fixation. However, the current study shows that NWB increases early implant failure and may also lead to fracture-healing delay and non-union; the complications related to prolonged bed rest as deep venous thrombosis (DVT) and pulmonary embolisms (PEs), pneumonia, cardiovascular diseases [36], pressure sources and infection also need to be seriously taken into account. The mortality rate has been shown to be lower in patients whom were allowed to immediately weight bear after proximal femur fractures [21]. Furthermore, the length of hospital stay and the economic burden related to it are often reduced in patients whom started early rehabilitation and mobilization with a quicker return to function [37].

This is a retrospective study which analysed the results of a cohort of patients treated by different surgeons in a level-I major trauma centre. Limitations of this study are those inherent in any retrospective case series. A potential criticism is that we did not have any method of confirming whether patients were compliant with their respective rehabilitation protocols. However, this may increase the external validity of the results as in clinical practice we do not have a real way to control patients' compliance. Similarly, there were multiple surgeons and physiotherapists involved in the study as well as different techniques were used to fix the fractures: this has the potential to introduce significant variability and hence reduce the internal validity of the study; however, it increases the external pragmatic validity of the study and the applicability to the clinical practice.

## Conclusion

This study shows that EWB in distal femoral fracture fixation is safe and does not compromise surgical fixation, neither does it increase the immediate post-operative risks. We propose that distal femoral fractures should not be treated differently from proximal femoral fracture in terms of post-operative rehabilitation instructions as early function recovery and early discharge should be the goal in all patients.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

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