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# Immediate weight bearing after plate fixation of fractures of the tibial plateau

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ABSTRACT

*Background:* Proximal articular fractures of the tibia are commonly stabilised with internal fixation using plates and screws. There is a lack of evidence and conflicting guidelines as to the most suitable post-operative rehabilitation regime including weight bearing status. There are numerous physiological and socioeconomic benefits of early weight bearing after orthopaedic surgery, but concerns remain around loss of fracture reduction. Therefore, the aim of this study is to investigate whether the weight bearing status after tibial plateau plate fixation is associated with any loss of reduction or articular collapse.

*Methods:* We retrospectively analysed data from our prospectively collected major trauma centre database. All tibial plateau fractures that required open reduction and internal fixation with plate and screws were included. The immediate post-operative weight bearing status of these patients was recorded. Group I consisted of those patients that were either non-weight bearing or touch weight bearing for the first six post-operative weeks. Group II consisted of patients who were instructed to weight bear fully (as tolerated) immediately after the operation. Radiographs were taken on day one post-operation, at six weeks and at three months and analysed for fracture displacement and joint depression or loss of fixation.

*Results:* A total of 90 patients were included in the study. Group I (non-weight bearing or touch weight bearing) consisted of 60 patients (67%). Group II (full weight bearing as tolerated) consisted of 30 patients (33%). The follow up radiographs demonstrated no failure of fixation in either study group. One patient from the weight bearing group had >1 mm joint depression (4 mm) identified at the first follow up, which did not progress.

*Conclusions:* This study shows immediate post-operative full weight bearing does not affect the fixation or cause articular collapse up to three months after surgery and thus we propose that patients should be allowed to weight bear immediately after surgical stabilisation of tibial plateau fractures. This will enable patients to benefit from the positive effects on fracture healing of early weight bearing post-surgery and avoid the complications of non-weight bearing without loss of fixation or articular collapse.



## Introduction

Proximal articular fractures of the tibia are commonly stabilised with internal fixation using plates and screws. Patients with tibial plateau fractures fixed with internal fixation are traditionally instructed to avoid weight bearing for some time after surgery to protect the fixation and avoid loss of reduction. Additionally, other complications of internal fixation of these fractures include stiffness, pain, and poor functional outcome [1–3].

There is no consensus for the most suitable post-operative rehabilitation and weight bearing status with regards to tibial plateau fractures fixed with plates. Arbeitsgemeinschaft für Osteosynthesefragen (AO) Guidelines advise toe-touch weight bearing for six to eight weeks and up to ten to twelve weeks toe-touch weight bearing for high energy injuries [4]. Many orthopaedic surgeons do not allow their patients to weight bear for the first six weeks after surgery, fearing loss of fracture reduction and articular collapse. Van der Vusse et al. highlighted the lack of consensus on post-operative management [5]. They showed that amongst a survey of Dutch orthopaedic surgeons, a large majority do not follow the AO guideline or their local guidelines. Only 11.7% of surgeons questioned recommended weight bearing immediately and 4.2% at two weeks. More than 55% non-weight bear their patients until six weeks post operation.

Behind this lack of consensus is a lack of evidence in the literature and conflicting guidelines. Currently, there is no

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evidence to support any one specific post-operative weight bearing protocol [6,7]. More recent small studies have shown no difference in outcome for post-operative non-weight bearing and weight bearing protocols [8].

In addition to minimising the risk of fracture collapse and fixation failure by non-weight bearing patients, there are also benefits to immediately weight bearing post tibial plateau fixation. These include physiological benefits such as improved bone healing [9]; decreased energy expenditure when mobilising [10]; decreased risk of venous thromboembolism [11]; socioeconomic benefits such as speed of return to work [12]; and a shorter stay in hospital [13].

Given this lack of consensus and guidelines on weight bearing after tibial plateau fractures treated with plate fixation, this study sought to investigate whether immediate post-operative weight bearing is associated with loss of reduction and articular collapse.

## Materials and methods

Data from a major level I UK trauma centre was analysed retrospectively from a prospectively collected database of all patients treated surgically for tibia plateau fractures between January 2015 and June 2017. All tibial plateau fractures that required open reduction and internal fixation with plate and screws were included. The technique used for fracture fixation was at the operating surgeon's discretion. A plate in buttress mode was used wherever appropriate. Locked screws were typically used across the articular block if appropriate. Non-locked screws were generally utilised in the shaft. The number and position of plates was according to fracture pattern. Neither cancellous or synthetic bone graft was used in any of the operations. Patients who were treated conservatively or with percutaneous screw fixation, external fixation (pin to bar fixator or circular ring fixator) or intramedullary nail were excluded. In addition, paediatric patients (less than 18 years of age) and pathological fractures secondary to malignancy or infection were excluded. Demographic patient data, operative data and radiographic data were collected.

The immediate post-operative weight bearing status of these patients was recorded and divided into two study groups. Group I consisted of those patients that were either non-weight bearing or touch weight bearing (the foot or toes may touch the floor to maintain balance, but not support any weight) for the first six post-operative weeks. Group II consisted of patients who were instructed to weight bear fully (as tolerated) immediately after the operation.

An immediate post-operative radiograph was taken at day one or day two post operation. In addition, radiographs at six weeks and three months post operation were taken. All radiographs were reviewed by two independent doctors and then compared. Radiographs were analysed using the IntelliSpace Picture Archiving and Communication System (PACS) Enterprise Version 4.4.516.15 with magnification 115%. Each radiograph was analysed for fracture displacement and joint depression or loss of fixation, standardised against the immediate post-operative radiograph. Displacement and joint depression was considered significant if there was displacement of more than 1 mm at the fracture site, compared to the immediate post-operative radiograph (factoring for radiograph magnification). A line was drawn from the medial corner of the tibial joint margin to the lateral joint margin. The perpendicular distance from this line to the elevated fragment was measured (Fig. 1). This was repeated on the follow up radiographs and the difference between the immediate post-operative radiograph and the follow up radiograph was measured. Statistical analysis was performed using the statistical program SPSS ver.23 and the statistical significance was set to 0.05.

## Results

During the study period, 118 patients with 120 tibial plateau fractures were identified. After exclusions, a total of 90 patients treated with plate fixation were included in the study. The mean age of the cohort was 45.1 ± 16.5 (19–91 years) with 66% being male. 51% of the patients had a Schatzker II tibial plateau fracture (lateral tibia condyle split depression), and the remainder were Schatzker I, IV and VI fracture patterns (lateral split, medial plateau fracture and metaphyseal-diaphyseal dissociation respectively). There were more Schatzker II tibial plateau fractures in group I as proportionally group I represented a larger percentage of the study population. Table 1 summarises fracture type and weight bearing status.

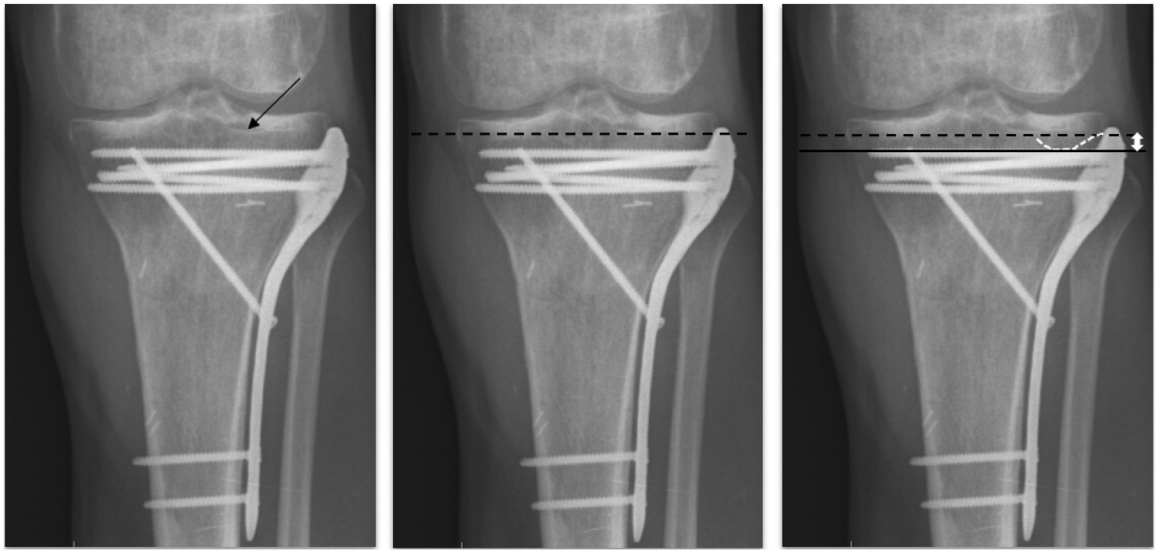

**Fig. 1.** Measurement of articular depression.
a) Immediate post-operation antero-posterior radiograph. Elevated fragment (noted with the arrow) is used for reference. b) Reference line (dotted line) is drawn at the level of the elevated fragment. c) Follow-up antero-posterior radiograph. Depressed fragment is noted with white dotted line. Measurement line is drawn at the level of depression (solid line). Measurement of the depression performed from the difference of the two lines (white arrow).

**Table 1**
Fracture type and weight bearing status.

| Fracture Type (Total = 90) | Non-Weight Bearing (n = 60) | Full Weight Bearing (n = 30) |
|---|---|---|
| Schatzker I | 1 | 1 |
| Schatzker II | 30 | 16 |
| Schatzker IV | 17 | 6 |
| Schatzker VI | 12 | 7 |

Fifty-five patients were treated with one lateral proximal tibia peri-articular plate (61%). Fourteen patients were treated with one medial or posteromedial plate (16%) and 18 patients underwent dual plating with a supplementary medial or postero-medial plate along with a lateral peri-articular plate. Three of the patients were treated with triple plating (lateral, medial and posterior).

Group I (non-weight bearing or touch weight bearing) consisted of 60 patients (67%), mean age 41.8 ± 15.2 years, range 19–82 years. Group II (full weight bearing as tolerated) consisted of 30 patients (33%) (mean age 51.6 ± 17.4 years, range 22–91 years). There was no difference in fracture classification between the two groups ($p = 0.82$).

The first radiographic assessment was completed on day one or day two after surgery, then at six weeks and then at three months. At the six week follow up, twelve (20%) patients were lost from the non-weight bearing group and three (10%) patients from the full weight bearing group. The follow up radiographs demonstrated no failure of fixation in either study group. One patient from the weight bearing group had >1 mm joint depression (4 mm) identified at the first follow up, which had not progressed or worsened by the second follow up. Fisher's exact test revealed no statistically significant difference in either depression or loss of reduction between the two study groups at six weeks ($p = 0.36$) and three months ($p = 0.37$).

The mean BMI of the cohort 25.4 ± 4.3 kg/m$^2$. Group I mean BMI was 25.3 ± 4.6 kgm$^2$ and group 2 mean BMI was 25.9 ± 3.5 kg/m$^2$. There was no significant difference between the two groups ($p = 0.58$).

## Discussion

There is little consensus on the optimum weight bearing status immediately post plating of tibial plateau fractures. This study has aimed to answer this question by showing that immediate post-operative full weight bearing does not affect the fixation or articular collapse. There are many benefits to full weight bearing after fixation of a fracture, including potentially improved fracture healing, global health benefit and socioeconomic benefits. Furthermore, there are challenges around compliance with restricted weight bearing regimes, and huge physiological and social issues surrounding non-weight bearing in the elderly.

In terms of bone healing, it is widely accepted that early stimulation (early weight bearing), equates to good early callus and healing which subsequently leads to early union and increased function. Robert Danis M.D. (1880–1962) proposed the principles of internal fixation. These include complete restoration of bone shape; union without callus; and most importantly, early active remobilisation [14]. Elliott et al. described their unified bone theory [9], which uses the concept of the "bone-healing unit" and involves three principles; Wolff's Law [15]; Frost's concept of the mechanostat [16]; and Perren's strain theory [17]. Wolff's Law which was later refined by Frost, describes the way physiological normal bone responds to mechanical stress. The greater the stress, the greater the remodelling [15]. This modelling involves electric charges with the electropositive tension side stimulating osteoclasts and the electronegative compression side, stimulating osteoblast formation. Therefore, if there is no stress, as in a non-weight bearing patient, there is no healing and remodelling.

Perren described the importance of strain in bone formation following a fracture. After a fracture, the sequentially differing tissue types progressively stiffen the area surrounding the fracture until the strain is low enough for bone to form. In a very low strain environment such as non-weight bearing the normal fracture healing process including granulation tissue, callus formation and bone formation is not able to occur due to a mismatching of the strain around the fracture site [9,17]. Claes et al. showed that osteoblasts align perpendicularly to strain equal to 4% or more. They measured up to 12% strain where the osteoblasts were predominantly aligned. This was dose-dependent and at lower strains, the osteoblasts were aligned randomly [18]. So we can see that clearly stimulation leads to early callus formation and also improved quality of callus.

It has also been demonstrated that there are difficulties with patient compliance when partial or non-weight bearing. Hurkmans et al. showed that when patients are given restricted weight bearing guidelines, the specific target load was not achieved by the patients post total hip replacement. This was especially highlighted with lower loads [19]. Dabke et al. showed that on average, patients exerted a mean of 35.3% of body weight more than that prescribed [20]. Vasarhelyi et al. go one step further to propose that post-operative partial weight bearing is not valid during clinical practice [21]. Therefore, when we advise a patient to have a period of restricted weight bearing, it seems unlikely they will be able to follow the instruction.

The effects of non-weight bearing has significant implications for the musculoskeletal system. An extreme example of non-weight bearing is experienced by astronauts in zero gravity flight, who suffer significant bone loss. Dual Energy X-ray Absorptiometry (DEXA) studies show bone loss of 0.9% per month in the lumbar spine and 1.5% per month in the femoral neck due to increased bone resorption whilst in space [22]. Shanb et al. demonstrated that the addition of weight bearing exercises in patient with osteoporosis increased the bone mineral density (BMD) more than non-weight bearing exercises [23]. Kortebein et al. showed ten days of bed rest in healthy older adults decreased maximum aerobic capacity, decreased knee extensor strength, decreased stair climbing ability and increased time spent inactive [24]. 25 years ago, Dittmer et al. demonstrated that prolonged bed rest and immobilisation inevitably leads to complications. These include loss of muscle strength (10–15% loss of strength per week), contracture and ligament weakness [25]. Other medical complications include an increased risk of venous thromboembolism [11], pulmonary complications, bed sores and a longer stay in hospital [13].

In the elderly, these deleterious effects of non-weight bearing are clearly significant and have major implications. Whilst there is certainly greater anxiety about early weight bearing articular fractures in the elderly due to poor bone quality, the work done on treating hip fractures has led the way on weight bearing post fracture in the elderly. Clement et al. suggest that the principle of early surgery and mobilisation of hip fractures may be extended to other lower limb fractures [26].

In the young, the concern around non-weight bearing is more about limiting the return to function and the deleterious effect on the limb. Early weight bearing may improve function and speed of return to work providing a greater socioeconomic advantage [12,27,28]. Contrasting this, non-weight bearing is associated with a decreased loss of independence and decreased ability to perform activities of daily living. Shanb et al. show that the addition of weight bearing exercise programs in patients with osteoporosis improves quality of life [23]. It is also noted that laboratory studies prove that energy expenditure when a patient weight bears is

much less than in those patients who are non-weight bearing. There can be up to a fourfold increase in the energy needed for non-weight bearing compared to full weight bearing [10].

Similar studies to ours have looked at early weight bearing after ankle fixation. These have demonstrated early weight bearing accelerates return to work and daily activities [29]. One paper cites loss of reduction in only 4% (one out of 26 patients) of ankle fractures [30] and another RCT demonstrated no increased risk of wound complications, infections or fixation failure or loss of reduction [31].

With regards to tibial plateau fractures, previous studies suggest no detrimental effect from early weight bearing. Segal et al. followed 86 tibial plateau fractures post treatment (mean 22.7 months) and the effects of early weight bearing in a cast brace. The cast brace was applied between ten to 14 days after the operation, after which, the patients could weight bear as tolerated. The cast brace was stressed into varus to offload the fracture site. 44 patients were treated operatively and showed no loss of articular reduction greater than 2 mm in any of the patients. They also reported 86% satisfactory outcomes in the surgical group, which included mild pain, range of movement of >10 degrees to 90 degrees and return to previous activity level without the use of walking aids. However, it must be noted that all patients were weight bearing in a cast brace that offloaded the fracture site [32], whereas in this study, the patients were allowed to mobilise unrestricted.

Haak et al. reported on 32 patients with tibial plateau fractures treated with locking plates. Twelve were allowed to weight-bear immediately and the remaining 20 were non-weight bearing until six to eight weeks. There was no radiographic displacement or failure of metalwork although functional outcomes were not assessed [8]. Only locking plates were assessed in Haak's study, whereas in this study, locking and non-locking plates, as well as non-locked screw constructs were included. Soloman et al. placed radiopaque beads into tibial plateau fractures fixed with locking plates in seven patients. At one year, they demonstrated an average loss of reduction of only 0.34 mm in the craniocaudal direction. Without the radiopaque beads, there was no subjective displacement seen on the radiographs [7]. Eggli et al. permitted 10Kg of weight bearing in 14 patients with high energy patterns who were treated with dual plating. None of the patients experienced loss of fixation or loss of reduction, but again, this was not full weight bearing [33].

More recently, Thewlis et al. looked at patient reported outcomes for 17 patients post open reduction and internal fixation for tibial plateau fractures. The patients were advised to load their limb to a maximum of 20 kg for the first six weeks. There were no associations between weight bearing ratio and patient reported outcomes at 52 weeks postoperative and no migration of fracture on radiographs at 52 weeks. They concluded that weight bearing as tolerated does not negatively affect the results of tibial plateau fractures [6]. However, these patients were only allowed to load their limb to a maximum of 20 kg for the first six weeks, as opposed to our study where patients were allowed to fully weight bear.

These papers support our findings, but involve fewer patients. In addition, Soloman et al. and Eggli et al. only permitted partial weight bearing as opposed to full weight bearing as in our study. Here we report the largest series of cases allowing patients to full weight bear unrestricted without a brace, immediately post operation.

We present the comparison of 90 patients from a single centre that presented with Schatzker type I, II, IV & VI fracture patterns and were treated with open reduction and peri-articular plate and screw fixation. Neither cancellous or synthetic bone graft was used in any of the operations. 60 of the patients were non-weight bearing or toe touch weight bearing for six weeks and the remaining 30 patients were advised to weight bear as pain allows immediately post operation. Follow up radiographs show only one patient from the weight bearing group had >1 mm joint depression on the two follow-up radiographs. This patient's clinical outcome (function and clinical examination) was not worse than the others in the cohort. This supports the existing literature in concluding that weight bearing post tibial plateau fixation, does not cause loss of fixation or joint depression, but with a greater number of patients.

There are two main limitations of the study; patient allocation bias and the number lost to follow up. Patient allocation bias was minimised by there being no difference in the spread of the fracture patterns and age between cohorts. With regards to number lost to follow up, at the six week check, there were only 20% and 10% lost in the non-weight bearing and weight bearing groups respectively. This increased at the three month check by which point the chance of collapse has disappeared as demonstrated in other studies and their time points. This still provides the biggest cohort to date for fully weight bearing post fixation of tibial plateau fractures.

## Conclusion

There is little consensus on the optimum weight bearing status immediately post plating of tibial plateau fractures. This study has aimed to answer this question by showing that immediate post-operative full weight bearing does not affect the fixation or cause articular collapse up to three months after surgery. We therefore propose that patients should be encouraged to weight bear immediately post operation. This will enable patients to benefit from the positive effects on fracture healing of early weight bearing post-surgery and avoid the complications of non-weight bearing without loss of fixation or articular collapse in plate fixation of tibial plateau fractures.

## Conflict of interest

None.

## Funding

Nil.

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