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ORIGINAL ARTICLE

Clinical outcomes in periarticular knee fractures with flexible fixation using far cortical locking screws in locking plate: a prospective study

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Abstract

Purpose Periarticular fractures around the knee joint are treated traditionally by locking plates which provide excellent stability but suppress callus formation. Far cortical locking (FCL) screws allow axial motion and enhance uniform callus formation. Our study aims to evaluate the outcomes of FCL screws in traditional locking plate in periarticular fractures of the knee.

Methods Thirty patients with periarticular fractures of the knee joint were operated with locking plate using FCL screws. All patients were evaluated clinically and radiographically using X-rays at 6, 12, 24 weeks, 1 year and with CT scan at 12-weeks follow-up.

Results The average time for complete union was 20 weeks in tibial fractures and 24 weeks in femur fractures. Average time to full weight bearing ambulation was 4.8 ± 0.93 weeks. One patient had delayed union in which union was complete after 9 months.

Conclusion This study shows that FCL screws in locking plates allow uniform callus formation and fracture union with minimal complication rates.

Keywords Far cortical locking screw · Locking plate · Periarticular knee fractures · Tibial plateau · Distal femur

Introduction

Periarticular knee fractures are challenging injuries to treat with a predilection to complications such as delayed union, non-union and implant failure [1]. Most of these injuries have significant comminution, are associated with poor vascularity of fracture fragments and therefore require bridge plating principle for fixation [2]. The introduction of locking plates has facilitated minimally invasive fixation with a stable construct along with preservation of vascularity in these fractures leading to good functional outcomes.

Though locking plates provide an appropriate biologic environment for fracture healing, the inherent rigidity of the construct is mechanically deleterious for healing of fracture ends. Locking plates have been proven to inhibit callus formation especially in the near cortex leading to suboptimal fracture healing [3, 4]. Studies in animal models and clinical scenarios have consistently shown that locked plating yields deficient and asymmetric callus formation near the near cortex due to lack of interfragmentary motion owing to rigidity of construct [5, 6]. This has resulted in a reported incidence of non-union in distal femur fractures as high as 16–23% [7, 8].

To reduce the complications arising from the rigidity of the locking plates, far cortical locking (FCL) concept was introduced in which the screws lock rigidly into the plate and into the far cortex but have a controlled motion envelope in the near cortex [9]. The elastic shaft portion of these screws deflects within the motion envelope created and thereby induces symmetrical axial motion at the fracture site akin to an Ilizarov fixator, thereby inducing the formation of a symmetrical callus [10]. The aim of this prospective study is to evaluate the clinical, radiological and functional outcomes in Indian patients who sustained periarticular fractures around the knee joint and underwent fixation with FCL screws and standard locking plate (Fig. 1).

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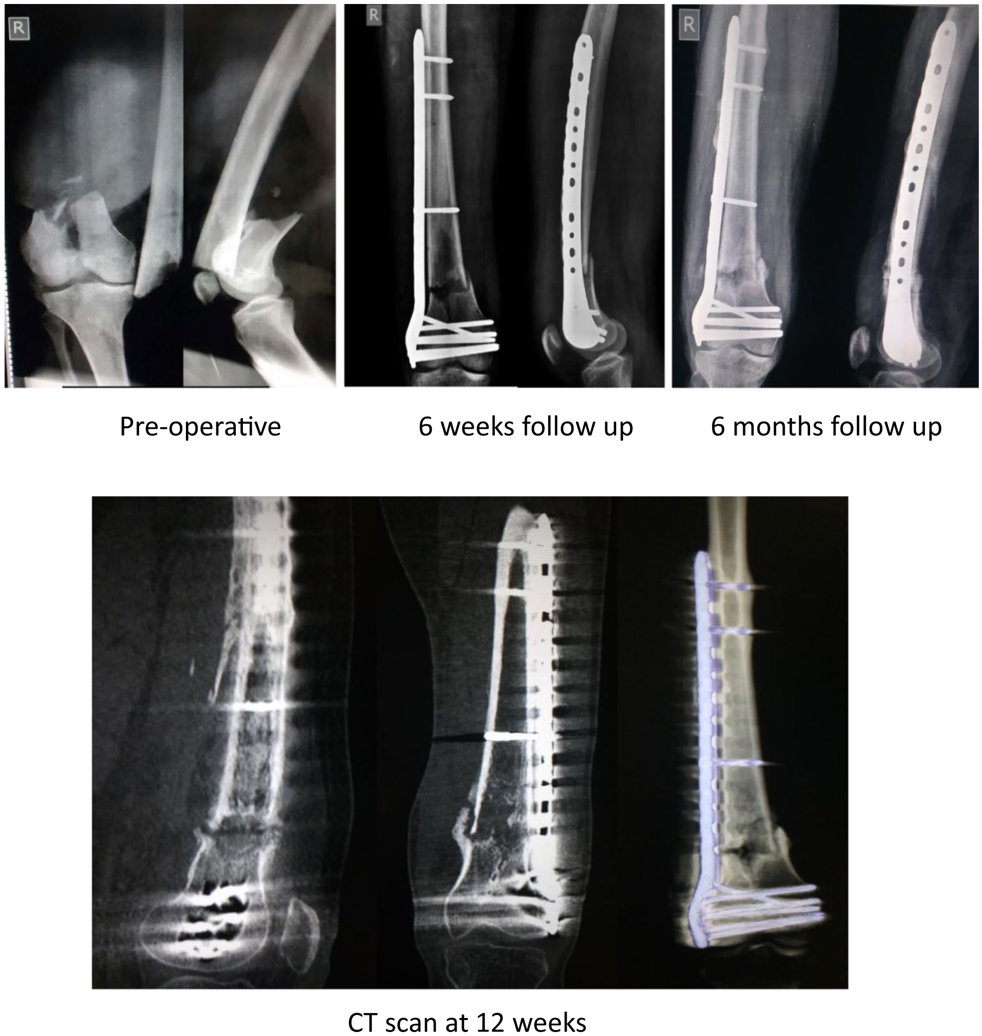

Fig. 1 Shows distal femur fracture fixed with FCL screws in a 40-year-old male patient which shows bridging callus formation in all the four cortices and complete fracture healing on X-rays and confirmed on CT scan

Patients and methods

This prospective observational study was conducted in a high-volume trauma center in which all patients who presented with distal femur or proximal tibia fractures between June 2015 and June 2016 were studied. Among them, 31 patients who were aged above 18 years, sustained acute fractures of proximal tibia or distal femur and were operated with FCL screws were included in the study. Patients who were pregnant, sustained compound fractures, pathological fractures or had neglected fractures (> 1 months old injury) were excluded from the study. The entire study was approved by the institute ethical committee prior to commencing the study and was conducted according to the principles established in the Declaration of Helsinki. Consent for the publication of clinical details, radiographs and photographs was obtained from the patients.

After fracture identification and reduction under image intensifier guidance, all the fractures were stabilized with a pre-contoured generic stainless steel locking plate in which cancellous locking screws were used for fixation in the metaphyseal region and FCL screws (generic) were used for diaphyseal fixation. These FCL screws are similar to the routine locking screw except that they are non-threaded at the proximal aspect of the shaft and therefore do not engage the near cortex of the diaphysis. The fracture site was dynamized by ensuring that the plate was not compressed to the diaphysis and ensuring that no screws were placed across the fracture site which can inhibit interfragmentary motion. Minimum three FCL screws and biologic bridge plating technique that aimed for soft tissue preservation were used in all the fractures. Postoperatively, all the patients were started on knee range of movement exercises as tolerated along with quadriceps strengthening exercises and weight bearing started after the fracture has been confirmed to be united.

All the patients were followed up to a minimum of 1 year and were evaluated clinically and radiologically during each visit at 6, 12, 24 weeks and 1 year. Patients were evaluated clinically for pain, range of motion of knee joint and weight bearing status during each visit, and the end point was defined as the absence of pain at the fracture site during load bearing. Radiographic analysis was done using biplanar X-rays done immediately after the surgery at each follow-up in which the formation of callus was noted and radiographic union score was calculated using the technique described by Whelan et al. [11]. The callus formation at each cortex was evaluated, and a numerical value was assigned according to the following scale: 0 = no visible callus; 1 = callus present but not bridging; and 2 = bridging callus. A CT scan was obtained at 12 weeks to evaluate cortical bridging and periosteal callus formation. The end point of radiographic union was defined as the presence of bridging callus in three out of four cortices on the radiographs and the presence of cortical bridging on the CT scan. Complication was defined as loss of reduction visible as change in varus alignment, implant failure, infection or non-union necessitating revision surgery. Patients whose fractures were not united even after 1-year follow-up were kept under observation till fracture united or revision surgery was done whichever was earlier.

Statistical analysis

Where applicable, observations were reported as mean ± standard deviation. Sample-matched analysis was performed to assess difference between two variables such as age and sex.

Results

Among the total study group of thirty-one patients, thirty patients were included in the study group and one patient was lost to follow-up. Among them, a total of 14 patients had proximal tibia fractures and 16 patients had distal femur fractures (Table 1). There were 17 male patients and 13 female patients in the total study among which six patients had a history of smoking and eight patients had diabetes mellitus. A total of 144 FCL screws were placed in total among which 84 screws were placed in femur and 60 screws were placed in tibia. At the end of 1 year, no patient required revision surgery or had implant failure or failure of fixation. The average time for complete callus formation was 20 weeks in tibial fractures and 24 weeks in femur fractures, and average time to full weight bearing ambulation was 4.8 ± 0.93 weeks in all the patients. Using radiographic union score system, it was found that callus formation was evident at all the four cortices at the time of final union which was evident on CT scan as well. One patient with distal femur fracture had delayed union in which union was complete after 9 months and confirmed on a CT scan. The clinical complications noticed were knee stiffness in one patient, short limb gait and abductor weakness in one patient and extension lag in three patients. Gender-matched sample analysis yielded no significant difference in time to union (p value = 0.75) between both the sexes. In age-matched sample analysis, patients below 30 years showed faster union compared to patients aged above 60 years (p value = 0.02).

Table 1 Demography and fracture types and their relative percentage in study group

Parameters	*N* (%)	Mean ± SD	Range
Gender			
Male	17 (56.67%)		
Female	13 (43.33%)		
Age		43.2 ± 12	18–77
Smokers	6 (20%)		
Diabetes mellitus	8 (26.67%)		
Fracture type			
Femur			
A0/OTA 33A2	3 (10.0%)		
AO/OTA 33A3	2 (6.67%)		
AO/OTA 33C1	6 (20%)		
AO/OTA 33C2	5 (16.67%)		
Tibia			
AO/OTA 41 A2	1 (3.37%)		
AO/OTA 41 A3	12 (40%)		
AO/OTA 41C1	1 (3.37%)		

Discussion

Periarticular fractures around the knee especially those involving the articular surfaces are challenging to treat on account of high intensity of injury as well as the biology of the fracture. These fractures are stabilized by bridge plating using minimally invasive techniques in order to avoid extensive dissection, which can jeopardize the vascular supply of the fragments [2, 6]. Since bridge plating leads to interfragmentary motion between the fragments, these fractures unite by secondary healing through callus formation [12]. Rigid internal fixation with locking compression plate does not allow significant interfragmentary motion and results in asymmetric callus formation, especially no callus formation under the plate. This, therefore, has warranted the development of fixation system that can provide uniform interfragmentary motion while achieving stability which are some of the characteristics of FCL system [4, 5]. This study on the role of FCL screws in treating periarticular fractures around the knee has shown good results with complete union in all patients without any severe complications. Adequate callus was formed in all the patients, and full weight bearing ambulation was achieved across the spectrum of fractures. These results have reconfirmed the potential beneficial role of FCL screws in treating these fractures.

The principle of dynamization of fracture site to allow axial micromotion leading to good callus formation and thereby fracture healing was documented around 68 years back when the sliding plate was introduced [13]. However, this concept was largely forgotten until recently when Panagiotopoulos et al. [14] conducted a study in adult sheep fracture healing model which showed that axial loading facilitated faster callus maturation and bone healing. Subsequent studies by other researchers using elastic inserts between screw heads and plates have corroborated the role of micromotion in ensuring rapid and better callus formation [15, 16]. FCL screws lock into the plate and far cortex but allow movement at the near cortex of a diaphysis and enable controlled axial motion due the flexion of the shaft. This leads to a decrease in rigidity of the construct and an increase in construct strength in the osteoporotic diaphysis under bending by 21% and under torsion by 54% when compared to conventional locking construct [9]. The main principle in FCL screws is to achieve fracture healing using the biomechanical principle of external fixator using internal fixation by flexible fixation, progressive stiffening, alternation in the load distribution and interfragmentary motion [17, 18].

The effects of dynamization of FCL are evident as uniform callus formation at the fracture site, whereas the hallmark of rigid plate constructs is the complete absence of periosteal callus formation adjacent to the plate. The ability of FCL screws to induce parallel interfragmentary motion by acting as cantilever beams that undergo s-shaped flexion is believed to contribute to symmetric callus formation at the fracture [10, 19]. Uniform callus formation has been documented with the use of FCL screws system by Bottlong et al. [20] in a prospective study in which a computational algorithm model on CT scan was used to evaluate periosteal callus size. In our study, we observed uniform callus formation on the X-rays and CT scan on all the four cortices which corroborates the role of FCL screws in facilitating dynamization at the fracture site and decreasing the rigidity of the plate construct.

All the patients in our study had complete fracture union even though one patient with distal femur fracture presented with delayed union which went to unite after 9 months. The rate of non-union for distal femur fractures fixed with locking plate has been reported to be as high as 16–23%, whereas the results reported with the use of FCL screws has been minimal. While the reported results for distal femur fractures are better than traditional locking system in our study, they are comparable in proximal tibial fractures which have a high union rate and do not have the complications seen in distal femur fractures [21]. The number of clinical studies published on the use of FCL screws have been very few and have been reported only in fractures around the knee. Ries et al. [22] reported their findings in a group of 20 patients with periprosthetic distal femur fractures who underwent fixation with FCL screws out of which 18 patients showed a healing rate of 88.9%. The callus formed was more robust and uniform and was seen earlier compared to traditional locking plate. In a prospective study of 31 fractures by Bottlang et al. [20], 125 Motion Loc FCL screws were used in the diaphysis of distal femur fractures stabilized by plate osteosynthesis. They reported complete fracture union in 29 patients and two revisions for malrotation and non-union, respectively, after an average follow-up of 17 ± 4 months. One fracture displaced into varus, and all the fractures healed at an average of 15.6 ± 6.2 weeks. Adams et al. [23] evaluated the results of FCL screws in 15 patients with distal femur fractures retrospectively among which five patients had open fractures and two patients had bone loss. All the fractures united at an average period of 24 weeks without implant failure or requirement of the second intervention. Only one study has been published till date evaluating the role of FCL screws in tibial fractures. Rice et al. [24] compared twelve tibial fractures treated using FCL screws with ten patients treated by standard plating and noted similar fracture healing in both the groups and suggested that FCL system is not inferior to conventional plate. However, the authors have included both diaphyseal and articular fractures in their study group, whereas we have studied only proximal tibial fractures in our study group. Our study has similar results when compared to the other studies for distal femur fractures and proximal tibia and thereby corroborates the results of the existing studies.

There are some inherent limitations in this study, and the results must be interpreted accordingly. The short duration of follow-up of 1 year may not be able to predict the long-term effects of these screws. However, the duration of study was considered appropriate for studying fracture healing based on the previous studies published which concluded that FCL screws are effectively unloaded and shielded from subsequent implant or fixation failure once the fracture healing was documented on CT scan which was the case in this study [16, 20]. The lack of objective clinical scales or range of motion (ROM) along with the use of a routine CT scan without metal artifact reduction sequence (MARS) which cannot accurately evaluate bone callus formation can be considered as a draw back of this study. Another limitation is the lack of a control group involving locking plate which could have provided better conclusive results regarding this technique. However, the review of the literature of traditional locking plates has shown a high non-union rate when compared to FCL screws and correlates with the results reported in our study. We believe that a randomized control trial (RCT) will be helpful in conclusively reporting on the benefits of FCL screws vis-a-vis the traditional locking plate. This study helps in providing the necessary data for formulating and calculating the sample size in such a study.

In conclusion, this study concludes that FCL screws are better than traditional locking screws in distal femur fractures and are non-inferior in proximal tibial fractures. They show faster, better and uniform callus formation with less chances of failure. A larger study population involving a RCT with the use of routine postoperative 3D CT scan and callus extraction algorithms would help in providing us with conclusive results on the benefits of FCL screws.

Compliance with ethical standards

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

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