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Original Article

Technical difficulties and mechanical failure of distal femoral locking compression plate (DFLCP) in management of unstable distal femoral fractures

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Abstract: Objective of the paper is to portray the technical difficulties and mechanical failure of Distal Femoral Locking Compression Plate in the management of unstable distal femoral fractures. The primary outcome measure was defined as revision surgery due to implant failure with subsequent non-union. Secondary outcome measures were mal-union, delayed union, peri-implant fracture and infection. Functional outcome were evaluated using Schatzker & Lambert criteria. Thirty nine patients were available for final follow up. The rate of revision surgery as primary outcome measure was 7.69%. Mal-union was seen in 5.1%, delayed union in 7.69%, superficial infection in 10.25% and deep infection in 5.1% patients. All except three fractures united following index surgery. Functional outcome as per the Schatzker & Lambert Criteria was excellent in 20.5%, good in 48.7%, fair in 18% and failure in 12.8%. In sight of the findings of our study along with existing literature we propose for creating a fixation construct that is conducive for fracture healing by following principles of locking compression plating and augmenting stability by medial column reconstruction.

Keywords: Unstable distal femoral fractures, distal femoral locking compression plate (DFLCP), non-union, varus mal-union, fixation failure

Introduction

Distal femoral fractures represent less than 1% of all fractures and 4-6% of all femoral fractures [1, 2]. These fractures have a tendency of being unstable [AO type 33A2, 33A3, 33C2 and 33C3] with intra-articular comminution [3-5]. Regardless of the immense advancements in implant designs and surgical techniques for treating these fractures, the difficulties in fracture healing and high rate of complications with subsequent poor outcomes are still encountered [5, 6]. Currently there is no consensus regarding optimal treatment for these fractures [7, 8]. DFLCP is helpful in the management of unstable fractures by virtue of offering multiple points of fixation and ability to resist varus collapse [9]. As high as 32% of these patients may require revision surgery to achieve satisfactory outcomes [10, 11]. The causes and risk factors for these revision surgeries remain ambiguous. Few studies mention comminution, fracture type, osteoporosis, poor quality of reduction and unstable fixation due to poor application of the principles of locked plating system as the risk factors for poor outcome [1, 6, 12-15]. Moreover, options for revision surgeries following failure of index operation are limited (ORIF revision with single/dual plates, retrograde intramedullary nail with or without bone grafting) with variable healing rates [16-19].

There is paucity of literature regarding technical difficulties leading to healing complications with use of single lateral distal femoral locking compression plate (DFLCP) in management of unstable distal femoral fractures following index surgery. Hence, the objective of the paper is to portray the technical difficulties and mechanical failure of DFLCP in management of unstable distal femoral fractures following index surgery with their literature based explanations and provide recommendations to avoid such complications.

Methods

Study design

This is a retrospective study of the technical difficulties and mechanical failure of DFLCP in management of unstable distal femoral fractures. The duration of study was from January 2014 to December 2018. Fractures were classified using AO classification system [4]. The study was approved by the institutional ethical committee. Informed consent was obtained from all the patients. The study was performed according to the ethical standards of the 1964 Declaration of Helsinki as revised in 2000.

Inclusion and exclusion criteria

The inclusion criteria was skeletally mature (≥ 18 years) patients with unstable fracture patterns as described by Weight in 2004 (AO types 33A2, 33A3, 33C2 and 33C3) with closed as well as compound grade I and II fractures treated with single lateral DFLCP [20]. Patients with AO Type 33B fractures (Hoffa's fracture), stable fracture patterns (33A1 and 33C1), pathological fractures and compound grade III fractures were excluded from the study.

Data collection and measuring tools

The anteroposterior (AP) and lateral radiographs of the distal femur with knee were performed. Computerized tomography scan was done in selected cases where fracture geometry was not clear on plain radiographs. All X-rays were assessed to define whether inclusion criteria were met, followed by a detailed case sheet evaluation to check for exclusion criteria. Baseline characteristics and outcome measures were collected using operation notes, day-to-day progress reports from case sheets, discharge ticket and follow-up evaluation, pre and postoperative radiographs, including microbiological evaluation. Immediate post-operative AP & lateral radiographs were assessed for quality of reduction, postero-medial comminution or gap, plate length, working length (measured by the number of empty holes between the two screws closest to the fracture) and number of screws in proximal and distal fragment. Regular clinico-radiological assessment was done to check for any loss of alignment and to progress of union. Radiographically union was defined as bridging callus on at least three of four cortices on AP and lateral radiographs. The loss of alignment was dictated by measuring any change in mLDFA (mechanical lateral distal femoral angle; an angle of 87 ± 2 degree was considered normal). Functional outcome were evaluated using Schatzker & Lambert criteria based on pain, range of motion, knee alignment and articular congruity [13].

Outcome measures

The primary outcome measure was defined as revision surgery due to implant failure with subsequent non-union. The various risk factors studied were AO fracture type, velocity of injury, closed vs open fracture, quality of fracture reduction, posteromedial comminution or gap, working length of plate and duration of surgery. The secondary outcome measures were malunion, delayed union, peri-implant fracture and infection (superficial and deep). Deep infection was defined as infection requiring revision surgery for control of infection. The intra-operative characteristics studied were technical difficulties encountered in fixation with DFLCP. For better understanding of the principles of DFLCP fixation, the technical difficulties were classified into problems associated with: 1) Fracture reduction; 2) Plate positioning and guide wire placement; 3) Loss of reduction or alignment while screw placement; 4) Biomechanics of locked plating system.

Methods used to solve these difficulties were noted from the operative notes and the data obtained was used for discussion and analysis.

Statistical analysis

All statistical analysis was done using Microsoft office 2010. The calculation of averages and standard deviation was done using data analysis tool. Unpaired t test was used for continuous variables, whereas for categorical variables Fisher's exact test was used. A P value of < 0.05 was considered to indicate statistical significance. Statistical analysis is represented in **Table 1**.

Results

Study population and demographic characteristics

Fifty two patients with unstable distal femoral fractures were treated with single lateral DFLCP.

Table 1. Statistical analysis

Variable	Uncomplicated healing (n = 34)	Complicated healing (n = 5)	*P* value (< 0.05 = Significant)
Velocity of trauma (High/Low)	20/14	3/2	1.000
Open/Close #	9/25	2/3	0.608
AO # Type (A2/A3/C2/C3)	11/3/9/11	0/1/1/3	0.630
Quality of fracture reduction (Good/Poor)	28/6	1/4	0.011
Posteromedial comminution (Present/Absent)	6/28	5/0	0.008
Mean working length	4.4	3.4	0.087
Mean Duration of surgery (minutes)	104	112	0.060

Table 2. Demographic and operative details of patients

Total no. of patients available for final follow-up	39
Male:Female Ratio	26:13
Mode of injury	Road Side Accident = 23 Domestic falls = 16
Mean Age	67.4 years (Range 19-82 years)
Mean Follow-up	20 months (Range 18-26 months)
Mean duration of surgery	105 minutes (range 90 min. to 140 min.)
Mean length of Hospital stay	7.5 days (Range 5-14 days)

Forty three patients met the inclusion criteria whereas 9 patients were excluded (pathological fracture, compound grade III fracture, skeletally immature). In our study cohort of 43 patients, 4 patients were lost to follow-up, hence 39 patients were available for final follow up at 18 months [**Table 2**]. Among these 39 patients, there were 26 males and 13 females. Road side accidents were the mode of injury in majority of patients (n = 23) followed by domestic falls (n = 16). Mean age of patients was 67.4 years (range 19 to 82 years). Twenty eight were closed fractures, while 11 patients had open fractures. As per AO/OTA classification, there were 24 type C (ten C2, fourteen C3) fractures and 15 were type A (eleven A2, four A3) fractures. Average duration of surgery was 105 minutes (range 90-140 minutes).

Rate of healing complications

The rate of revision surgery for implant failure was 7.69% (n = 3). Among the various risk factors studied for failure of osteosynthesis, two variables namely, quality of fracture reduction and posteromedial comminution or gap was found to be statistically significant [**Table 1**]. The type of revision surgery in three patients was retrograde intramedullary nail (n = 1), single lateral DFLCP (n = 1) and dual plating with bone grafting (n = 1). Secondary outcome measures showed mal-union in 2 (5.1%), delayed union in 3 (7.69%), superficial infection in 4 (10.25%) and deep infection requiring revision surgery for control of infection in 2 patients (5.1%). No peri-implant fracture was seen. The mal-union was dictated by change in mLDFA (mechanical lateral distal femoral angle) in both patients. All except three fractures united following index surgery at a mean time interval of 24 weeks. Mean ROM achieved at knee was 114.0 ± 16.4. Functional outcome according to the Schatzker & Lambert Criteria were excellent in 8 (20.5%), good in 19 (48.7%), fair in 7 (18%) and failure in 5 (12.8%). At final follow-up, all patients except one with revision surgery (died due to end stage renal disease) were walking independently.

Rate of technical complications

Various technical difficulties encountered were failed closed reduction of metaphyseo-diaphyseal component (n = 6), improper plate positioning (n = 4), primary loss of reduction (n = 6), difficulty in putting distal screws due to locking sleeve mismatch (n = 3) and breakage of guide wire in two patients [**Table 3**]. The overall incidence of such technical complications was 53.8% (n = 21). Open fracture reduction was done in all six patients with failed closed reduction.

Table 3. Technical difficulties with implantation of DFLCP = 21 patients (53.8%)

Technical difficulty	No. of patients
Failed closed reduction	6
Plate positioning problems	4
Primary loss of reduction	6
Difficulty in putting distal screws due to locking sleeve mismatch	3
Breakage of guide wires	2
Fracture at plate end (Peri-implant fracture)	0

Discussion

Although DFLCP is technically demanding procedure, however; with proper application of technique it gives outstanding results even in unstable distal femoral fractures. The important technical aspects are attaining good reduction with acceptable valgus angle, making correct rotation, placing plate properly with precise placement of screws. The technical problems encountered in our study can be summarized under the following heads:

Problems associated with fracture reduction

The importance of anatomical fracture reduction while treating intra-articular distal femur fractures cannot be overemphasized. Choice of an appropriate surgical approach and technique (conventional direct open reduction vs indirect reduction) should be dictated by the fracture geometry, severity of soft tissue injury, patient factors, implant selection, and surgical skills of the operating surgeon. We aimed at achieving anatomical reduction of articular area, restoring length and alignment of the metaphysis to articular block. In our study indirect reduction technique failed in 6 patients, requiring open reduction (15.4%). Buckley in 2011 reported statistically significant incidence (38.5%) of femoral malrotation following fixation of distal femoral fractures using indirect reduction technique [21]. Outcome of distal femoral fractures is closely associated with the quality of fracture reduction [21-24]. Therefore, in case of an unacceptable indirect metaphyseal reduction one should not hesitate to do an open reduction to prevent subsequent failure [**Figure 1A-C**].

Problems associated with plate positioning and guide wire placement

When anatomically contoured plate is placed properly, it assists fracture reduction by restoring normal length and alignment. Contrary to this improper positioning of the plate causes mal-reduction of the already reduced fracture (primary loss of reduction). Cory recommends positioning of the plate within a centimeter of anterior edge of the lateral condyle and 1 to 1.5 centimeter above the joint line [6]. We encountered plate positioning problems in 4 (10.25%) patients which required several modifications to achieve proper plate position. Accurate positioning of plate ensures the placement of guide wire nearly parallel to articular surface of the femoral condyles, thus ensuring the restoration of desired normal valgus alignment [6].

Problems associated with loss of reduction or alignment while screw placement

Primary loss of reduction is a main concern when anatomically contoured plates are used for treating distal femoral fractures. We have 6 (15.4%) cases of primary loss of reduction while putting screws [**Table 3**]. In 3 of them, we corrected it by changing the screws, while in 3 cases it persisted as varus or lateralization of proximal fragment which resulted in healing difficulties. Therefore, reduction and accurate plate positioning should precede application of combination of compression and locking screws to avoid primary loss of reduction. As already discussed that orientation of guide wire and distal screws trajectory should be nearly parallel to articular surface of the femoral condyles for restoring desired 5 to 8 degrees of normal valgus. Any deviation from parallelism has impending risk of increased valgus or more disastrously varus mal-alignment.

Problems associated with biomechanics of locked plating system

A moderate axial motion and minimal shear movement between fractured bone fragments is desirable for fracture healing, too much or too little can delay or inhibit fracture healing

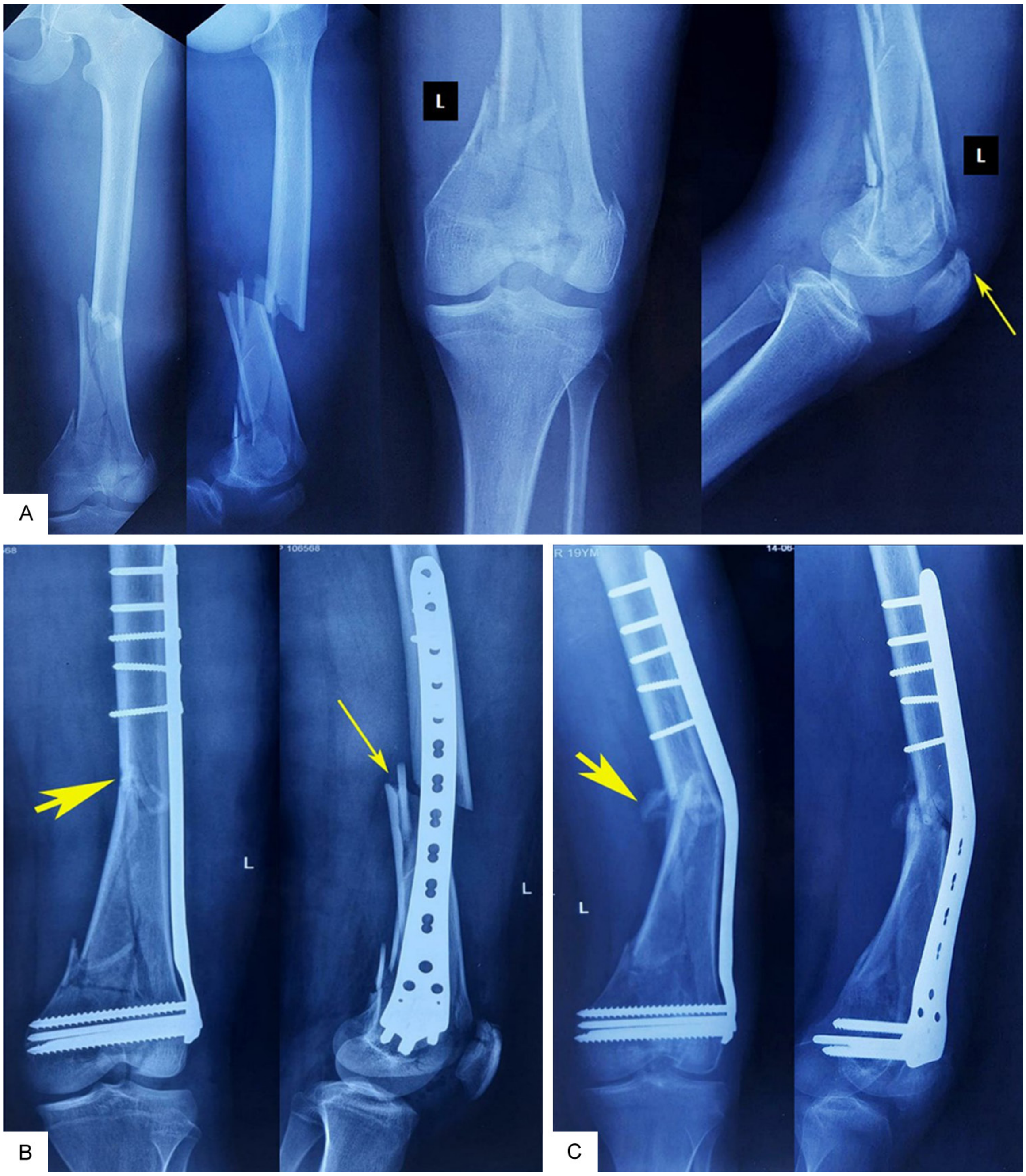

Figure 1. A. Pre-operative radiograph of patient with 33C2.2 fracture. Also note undisplaced fracture of superior pole of patella (arrow). B. Post-operative radiograph showing varus mal-reduction (thick arrow, AP view) and posterior sag (thin arrow, lateral view). Also note the large working length spanning a long medial unreconstructed segment of the fractured bone. C. Radiograph at 3 months showing plastic deformation of plate (fixation failure) with attempt at callus formation (thick arrow).

[25-28]. The axial micromotion produced by locked plating system are often altered by variables viz plate length, working length, the offset distance between the bone and plate, screw spacing and the material properties of the plate [26, 29-31]. Biomechanics of locked plating system is closely associated with the modulation of the mechanical environment in favour of fracture healing with appropriate level of axial micromotion. Failure to do so may result in fixation failure [**Figure 1A-C**]. Although, it is generally agreed upon that the plate length for

comminuted fractures should be 2 to 3 times longer than the fracture length, however the optimal screw position and type of screw on the proximal side of the locking plate are currently debated [29, 32-34]. Gautier recommends that ≥ 3 empty holes should be left around the fracture site, whereas Stoffel recommends that the screws should be placed as close to the fracture site as possible [29, 34] for comminuted distal femoral fractures. The working length of a locking plate is defined as the distance between the two closest screws across the fracture site and it is influenced not only by plate length but also by type of screws placement [35]. However, location and number of locking screws are commonly chosen by surgeon experience instead of scientific evidences [6, 9]. Although we agree with the Hoffman's recommendation to put at least three bi-cortical screws on either side of the fracture [22], but we recommend minimum 4 screws across the fracture site for unstable fracture pattern.

Healing complications

The healing complications developed subsequent to fixation of unstable fractures with the DFLCP are presented in **Table 4**. The rate of revision surgery due to healing complications following lateral locked plate fixation for distal femoral fractures has been reported to range from 0 to 32% [10, 11, 36-38]. We have done revision surgeries in 5 (12.8%) patients, 3 for fixation failure [**Figure 2A**, **2B**] and 2 for deep infection. Kregor, Schutz and Vallier have reported a revision surgery rate of 5%, 19% and 20% respectively in their studies [37-39]. In above mentioned studies the fracture patterns included were both stable as well as unstable; however in our study all fractures were unstable. Two asymptomatic mal-unions were not subjected to revision surgery due to patients' refusal. Among the fixation failure cases, all three patients were having poor quality of reduction [**Table 4**]. Poor quality of fracture reduction was statistically significant risk factor for revision surgery with p value = 0.012 (**Table 1**). Poor quality of reduction and residual gap at the fracture site predisposes to excessive local interfragmentary motion and subsequent failure [40], as seen in our study. We believe that the quality of fracture reduction is a crucial factor that affects the rate of revision surgery following osteosynthesis with DFLCP in unstable distal femoral fractures. In three patients with fixation failure we encountered plastic deformation of plate (n = 1) at 3 months [**Figure 1C**], broken plate (n = 1) at 6 months and en-bloc pulling out of distal screws at 2 months (n = 1) following index surgery. Henderson in 2011, classified the implant failures into early (≤ 3 months) and late failures (≥ 3 months) following index surgery. Early implant failure is due to mechanical instability secondary to either surgical technique or implant design, and late failure is likely related to healing issues where the implant experiences loading cycles that exceed its fatigue limit [10]. In two of our cases (plastic deformation of plate and en-bloc pulling out of distal screws) early failure was observed, which was related to mechanical instability due to technical errors. The early failures in our study emphasizes the need of refining the surgical techniques and proper application of principles of biomechanics of locked plating system. Toro also opined healing issues are more likely due to technical errors and stressed on improving the techniques [9]. Hsu reported early failure in 13.6% of his patients with complex distal femoral fractures treated by locked plating emphasizing mechanical instability as a possible risk factor for early fixation failure [41].

One of our patients with late failure presented with broken plate at 6 months, which was related to fracture healing rather than poor application of surgical technique. Holzman recommended addition of a medial plate and autogenous bone graft for aseptic non-unions with stable lateral construct as was in our case [42]. The addition of a medial plate along with bone graft enhances both mechanical and biological environment for bone healing to prevent subsequent late failure. Therefore, in patients lacking signs of progressive union in two consecutive orthogonal radiographs, we recommend an early application of medial plate and bone grafting rather than to wait for the development of an established non-union.

In our study cohort with fixation failure (n = 3) and mal-union (n = 2), all were having medial or posteromedial comminution, which was found to be statistically significant (p value = 0.008). Peschiera also reported high failure rates with poor medial alignment and discontinuity, and recommended for medial column reconstruction either with graft or medial buttress plate when a medial defect of 2 cm or more is observed in order to prevent fixation failure

Table 4. Healing complications

S. No.	Age & Sex	AO/OTA classification	Reduction	PL/WL#	No. of screws in proximal & distal fragment through plate	Fixation type	Complications	Revision surgery	Outcome
1	19/M	33C2.2	Long medial comminution, Varus & posterior sag	11/6	4 & 5	Flexible	Plastic deformation leading to Non-union (3 months)	Retrograde intramedullary nail	United
2	65/F	33A3.2	Long Medial comminution	9/4	4 & 4	Flexible	Fatigue Failure/Plate breakage (6 months)	Revision plating	United
3	82/F	33C3.2	Medial step and medial comminution	7/4	4 & 4	Flexible	En-bloc pulling out of distal screws (2 months)	Double plating with bone grafting	Patient died due to end stage renal disease
4	25/M	33C3.1	Postero-medial gap & lateralization of proximal fragment	7/2	5 & 4	Flexible	Varus collapse leading to varus mal-union + Delayed union	Not done	Varus mal-union
5	19/M	33C3.1	Medial comminution	5/1	3 & 3	Rigid	Varus collapse leading to varus mal-union + Delayed union	Not done	Varus mal-union

PL/WL- Plate length/Working Length: Working length is measured by the number of empty holes between the two screws closest to the fracture.

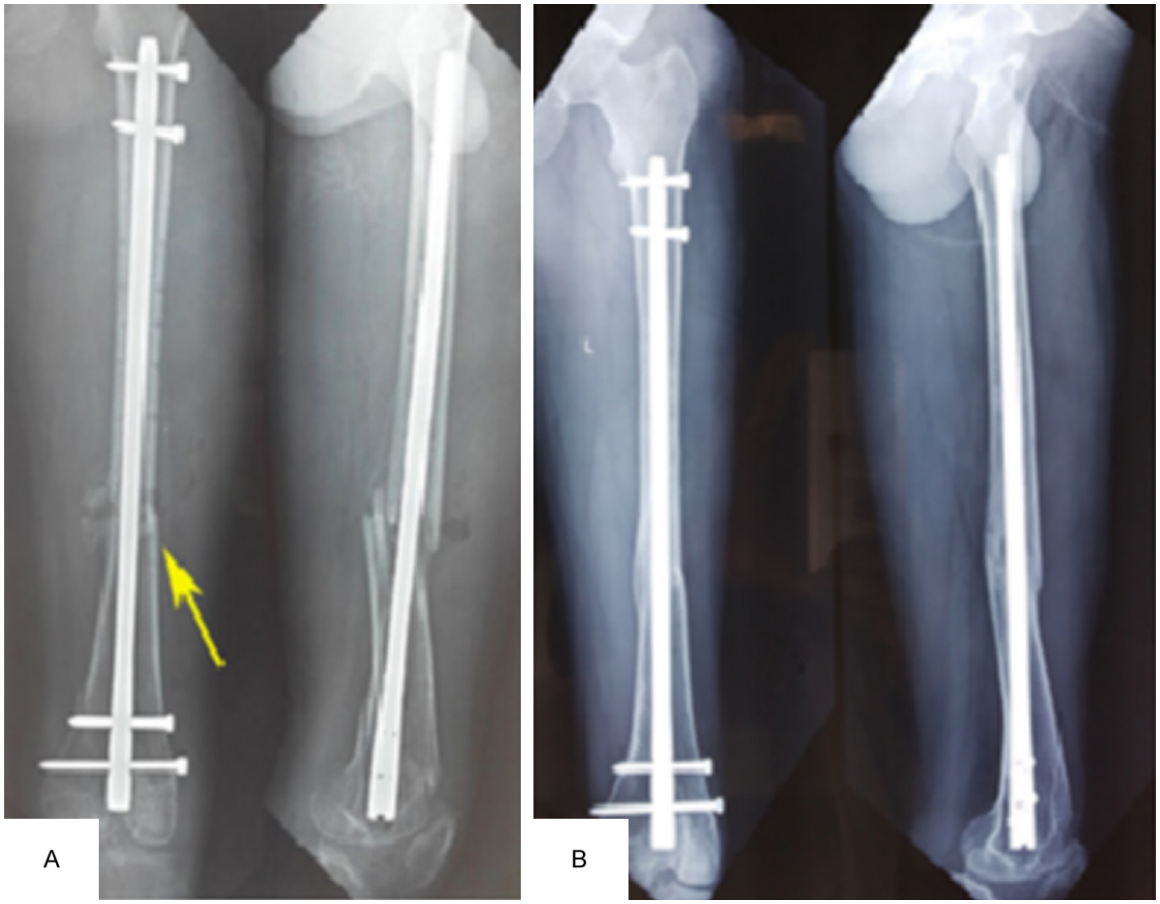

Figure 2. A. Radiograph showing revision surgery with retrograde intramedullary nail. Nail has corrected the varus mal-alignment (arrow), but posterior sag still persisting. B. Radiograph showing complete union. Also note the remodeling of posterior sag to some extent.

[43]. Prayson also recommends supplementation with medial column plating in similar fracture patterns [44]. Steinberg suggested double plate fixation for A3 and C3 type comminuted fractures to improve the rate of fracture healing [45]. Metwaly advocated double plating for intra-articular fractures of distal femur in elderly population to improve the stability of fixation [46]. We also believe that unsupported medial column lead to healing issues, necessitating medial column reconstruction in unstable distal femoral fractures with posteromedial comminution or gap.

There were 4 cases of superficial infection and 2 cases of deep infection. Superficial infection responded to conservative therapy, while the deep infections required operative debridement for successful healing of infection. In our study rate of deep infection was 5.1%, compared to 3% in studies done by Kregor and Schutz [37, 38]. We have not encountered any case of peri-implant fracture in our study.

Our study attempts to highlight the technical difficulties and mechanical failure of DFLCP in unstable distal femoral fractures following index surgery. The strengths of the study are inclusion of only unstable fracture patterns and fixation using single lateral plate. However, retrospective design, small sample size and lack of comparative groups are the limitations of current study. Future studies are required aiming improvement in the surgical techniques and augmenting stability of fixation in unstable distal femoral fractures.

Conclusion

Although DFLCP fixation is an established method of treatment of distal femoral fractures, yet the procedure is not free from complications. Considering the failures in our study, we believe that such complications are more of a technical and mechanical origin, instead of the failure of the implant. The important technical aspects are attaining good reduction with acceptable valgus angle, making correct rotation, placing plate properly with precise placement of screws. In sight of the findings of our study along with existing literature we propose for creating a fixation construct that is conducive for fracture healing by following principles of locking compression plates. Additional augmentation of medial column by medial plating or bone grafting or both is equally important to achieve satisfactory outcomes in such cases. Although surgery is technically demanding, a vigilant attention to minute technical details of the procedure as discussed above, can provide good outcome with acceptable rates of complications.

Disclosure of conflict of interest

None.

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