J Orthop Spine Trauma. 2019 December; 5(4): 103-6. DOI: http://dx.doi.org/10.18502/jost.v5i4.4380

Educational Corner

How to Prevent Distal Femoral Fracture Non-Union? Educational Corner

Sadulla Sharifpour[1], Alireza Moharrami[1], Seyed Mohammad Javad Mortazavi[2,*]

[1] Resident, Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran
[2] Professor, Division of Hip and Knee Surgery, Department of Orthopedic Surgery, Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran

[*]Corresponding author: Seyed Mohammad Javad Mortazavi; Division of Hip and Knee Surgery, Department of Orthopedic Surgery, Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-2161192767, Email: smjmort@yahoo.com

Received: 18 September 2019; **Revised:** 15 November 2019; **Accepted:** 11 December 2019

Keywords: Femur; Femoral Fracture; Fractures, Bone

Citation: Sharifpour S, Moharrami A, Mortazavi SMJ. **How to Prevent Distal Femoral Fracture Non-Union? Educational Corner.** *J Orthop Spine Trauma* 2019; 5(4): 103-6.

Background

Distal femoral fracture (DFF) is a common injury that often has an association with high-energy trauma in young population or low-energy trauma in the elderly. In this fracture, it is an important target to achieve excellent reduction and lower limb alignment. Most of DFFs are currently treated by open reduction and internal fixation (ORIF) with devices such as 95 angle-blade plates, condylar screws, locking plates, and retrograde intramedullary nailing (IMN) (1, 2). There are several complications following DFF fixation such as nonunion (NU). NU is a rare complication which can cause some major problems in the patient's quality of life (QOL) and functions. The etiology and treatment of distal femur NU remain as major challenges among orthopedic surgeons (3). Some known etiologies of NU include the complex fracture pattern, poor bone quality, poor reduction/fixation techniques, and patients' comorbidities (4).

Signs of fracture union include pain-free weight bearing and radiological signs such as formation of bridging callus. On the other hand, patients with NU of distal femur have painful weight bearing. Absence of progressive radiological healing in 3-month intervals up to 6 months after the fixation suggests NU of the fracture site (2).

In the present study, the aim is to examine the preventable causes of distal femur NU in four categories including fracture characteristics, fixation characteristics, patient's characteristics, and medications. This study was also developed to discuss how to prevent NU in DFFs as a significant complication, which affects patient's QOL and functions.

Choosing Devices

Several devices have been used for fixation of DFFs with good outcomes including condylar buttress plate, retrograde IMN, angle blade plate, and 95-degree dynamic compression plate (DCS) (5, 6). Davison reported higher fixation failure rate and NU for condylar buttress plate and 95-degree DCS (7) compared to the locked plate in DFF (8).

Lateral Locking Plate (LLP) and NUs

More recently, LLP has been considered as a standard method for DFF fixation because of some major advantages such as biomechanical properties to resist varus collapse, relative technical ease for implantation, and the opportunity to obtain multiple fixation points in the distal fragment, even in the setting of scant distal bone stock (9, 10). Some previous studies showed that distal femur fixation with LLP has good early outcomes (11, 12), with moderate NU rate and implant failure in later follow-ups (2, 13, 14). In the Southeastern Fracture Consortium in 2016, risk factors for NU and infection in a retrospective analysis on 339 patients fixed with LLP (185 pts) was compared with less invasive stabilization system (LISS) (154 pts). The study uncovered open fracture as a risk factor for NU and infection and reported a NU rate of 20 % (more than previous studies). Their study showed no significant difference between LISS and LLP (15). Hoffman et al. reported a NU rate of 18% among 111 patients with DFF who were treated by LLP. They showed no relation between NU and neither the plate's working length nor the length of comminution (16). Ricci et al. reported a 19% reoperation rate in 335 DDF patients (fixed by LLP) due to NU, infection, or implant failure. They recognized that open fracture (33%), smoking (24%), and diabetes mellitus (DM) (19%) were the major risk factors for NU (17). Moloney et al. reported a 24% NU rate in the geriatric patients with DFF fixed by LLP and they identified that surgical site infection (SSI) was significantly correlated with NU (18).

Association of Plate Design and Material with NUs

Both plate design and materials have significant effects on NU rate following DFF fixation. Besides, some studies identified that the use of stainless steel plates (NU rate: 44%) could increase the risk of NU compared to titanium plates (NU rate: 10%) (19, 20). Rodriguez et al. revealed that a high rigidity score is a predictive factor for NU in DFFs (20).

Double Locked Plating

Some studies have showed a relatively high failure risk for single LLP. There are limited data about using double plates in DFF fixation. Steinberg et al. developed a clinical study on 32 patients with DFF who underwent the double plating approach (lateral and medial plates). Their results revealed that this approach was appropriate for patients with poor bone quality, low periprosthetic fractures, and comminuted fractures (21).

In a study by Holzman et al. amongst 23 patients with distal femur NU, 16 were treated with single-stage addition of a medial locked plate in addition to a stable lateral plate. 7 cases with failed lateral plates underwent an LLP change followed by a medial locked plate after two months. In 20 out of 23 patients, union was achieved after a mean of 12 months. They recommended double plating

when NU is associated with fixation failure (22).

Construct Strength and Resilience

It is important to emphasize that the most distal locking screws must be parallel to the joint surface as assessed on anteroposterior (AP) image as a guide for restoring limb alignment. Before the operation, the plate length and number as well as placement of screws should be planned by the surgeon. Achieving the good outcomes requires meticulous techniques including minimal soft tissue dissection, longer working length, more screws in each segment, and more locked screws in the patients who had poor bone quality. When selecting the plate length, there should be eight or more screw holes above the most proximal aspect of the fracture if possible. The position of the plate must be referenced to Blumensaat's line and the subchondral margin of the trochlear groove (17).

Association of Fracture Patterns with NUs

It is important to know which fracture patterns are associated with higher rate of NU in DFF. Gardner et al. showed that NU more often occurs following open and/or comminuted fractures possibly due to the disruption of blood supply (3). Ebraheim et al. systematically reviewed the studies about NU in DFFs from September 2000 to June 2012. They concluded that metaphyseal comminution was the most common fracture pattern in DFF that end up with NU (8). The study showed that based on the Orthopaedic Trauma Association (OTA) classification (23), 33 A1 was the most common DFF (80.3% of the closed fractures), followed by metaphyseal comminuted fractures OTA 33A3 (11% of closed fractures), and OTA 33C1 (simple intra-articular fractures) (5.6% of close fractures), respectively (8). In open DFFs, they uncovered that based on the Gustilo-Anderson (GA) classification, the most common open DFF was GA IIIB and then GA IIIC and GA IIIA, respectively.

Preventing NUs

It is important to prevent NU in stable OTA A1 fracture as the most common type of DFF. The fracture should be well reduced and fixed to increase the stability and promote primary bone healing by compression techniques including eccentric drilling, use of tensioner devices, and push-pull screws with a large Verbrugge clamp. Following the surgery, the patient should begin earlier weight bearing to prevent NU. Nevertheless, using plates as load sharing devices presents certain limitations on the time of starting full weight bearing.

In OTA A3 (metaphyseal comminution) as the most common DFF pattern resulting in NU, the plate should act as an internal splint. In this fracture type, the aim is to promote secondary healing by bridge plating and reduce the fracture to the plate. For this purpose, it is necessary to prevent NU by performing a longer plate (8 holes), less soft tissue dissection, more locked screws, and less screw ratios (2:1 or one screw per 2 holes in plate) (17).

Patients

Previous studies investigated causes of delay in bone healing and NU. Smoking, DM, high body mass index (BMI), malnutrition, and non-steroidal anti-inflammatory drugs (NSAIDs) are frequently reported to impact bone healing and cause NU. However, effects of nutritional and endocrine optimization on bone healing have not clearly been investigated (8, 17, 19, 24, 25).

In a study by Brinker et al., in 37 of 683 patients with delayed healing, there were no clear vascular, mechanical, and infection-related causes for delaying. The patients underwent full endocrine evaluation. All endocrine parameters were corrected, and NUs were treated without any surgical intervention. The study recommended some endocrine tests for the evaluation of NU such as thyroid-stimulating hormone (TSH), free thyroxine (free T4), parathyroid hormone (PTH), 25 (OH) D, calcium, phosphorus, magnesium, alkaline phosphatase, testosterone, and hemoglobin A_1C (25).

Malnutrition

The role of nutritional optimization in the treatment of NU is not clearly identified. Moloney et al. recognized that in hypoalbuminemic geriatric patients with DFF, NU, infection, length of hospital stay (LOS), and 1-year mortality all increased (18). Using the nutritional risk screening (NRS 2002) method, Ihle et al. revealed that 20% of the patients with orthopedic traumas were at risk of malnutrition (26).

There are some typical recommendations including daily administration of proteins (1-2 g/kg). Furthermore, adequate vitamins and minerals such as Zinc, Vit C, Vit D, and iron as well as some immune nutrition including Arginine ± glutamine, Omega 3 fatty acids, and nucleotides are required to be taken (24).

Role of Medications

Vitamin D modulation has an impact on other minerals such as calcium and phosphorus (24). However, the effects of Vit D on fracture healing are not clearly understood. It is proposed that correcting Vit D levels in fracture patients may prevent NU (Table 1) (24).

Table 1. Vitamin D prescription in patients with traumatic fractures and non-unions (NUs)

25 (OH) D Level (ng/ml)	Medication	Prescription
20-32	50000 unit pearl Vit D	Weekly
10-20	50000 unit pearl Vit D	Twice a week
0-10	50000 unit pearl Vit D	3 times a week

There is an attitude among some surgeons that NSAIDs are contraindicated in patients with fracture or NU because of suppressing the inflammatory reaction and prostaglandin synthesis as a stage of bone healing. Bergin et al. reviewed the previous studies on the role of NSAIDs on bone healing following fractures and concluded that short term usage of NSAIDs had no significant effect on the incidence of NU, but in the long term it could increase the risk of NU (24).

Limited studies support the theory that PTH improves fracture healing, but the results are not enough for clinical recommendations. Teriparatide is a recombinant biologically active form of PTH which has been uncovered to increase bone mass and prevent fractures in osteoporotic bone. The Food and Drug Administration has licensed it for the treatment of osteoporosis. Over the last decade, a growing body of evidence has been accumulated suggesting the role of Teriparatide in the management of fractures. Studies in both normal and delayed healing models have shown improvement in callus volume and mineralization, bone mineral content, rate of successful union, and strength at fracture sites. Huang et al. retrospectively included 189 patients with osteoporotic intertrochanteric fractures in a study. They prescribed teriparatide for a group of patients following surgery for six months and reported significantly shorter time to union than the control group (27). In a controlled randomized study by Johansson, it was shown that there was no radiographic enhancement of union in the group who took teriparatide following proximal humerus fracture (28). In a study by Babu et al., the role of teriparatide in fracture/NU healing was reviewed. They concluded that many physicians use teriparatide as an

"off-license" drug for fracture healing but there are not enough evidence about using this drug in NU and delayed union. It seems that more trials are required to prove its effects on NU (29).

Many previous studies investigated the risk factors of NU following DFF fixation with LLP. Open fracture (15, 17, 19), smoking (17, 19), DM (17, 19), infection (15, 18, 19), obesity (19), utilizing stainless steel plates (19, 20), and high rigidity score of the construct (20) are significantly associated with distal femur. It might be beneficial to diagnose malnutrition in patients with DFF and prescribe appropriate supplements and minerals. The role of Vit D is not clearly specified, but prescription of Vit D is recommended in fractures as proposed in table 1. NSAIDs in short-term prescription have no significant effect on bone healing, but in long term may delay fracture healing. Finally, evidence to support medical therapy for the treatment of NU is not strong enough to make a clinical recommendation.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgments

None.

References

1. Henderson CE, Kuhl LL, Fitzpatrick DC, Marsh JL. Locking plates for distal femur fractures: Is there a problem with fracture healing? *J Orthop Trauma*. 2011;25(Suppl 1):S8-14. doi: 10.1097/BOT.0b013e3182070127. [PubMed: 21248560].
2. Henderson CE, Lujan TJ, Kuhl LL, Bottlang M, Fitzpatrick DC, Marsh JL. 2010 mid-America orthopaedic association physician in training award: Healing complications are common after locked plating for distal femur fractures. *Clin Orthop Relat Res*. 2011;469(6):1757-65. doi: 10.1007/s11999-011-1870-6. [PubMed: 21424831]. [PubMed Central: PMC3094618].
3. Gardner MJ, Toro-Arbelaez JB, Harrison M, Hierholzer C, Lorich DG, Helfet DL. Open reduction and internal fixation of distal femoral nonunions: Long-term functional outcomes following a treatment protocol. *J Trauma*. 2008;64(2):434-8. doi: 10.1097/01.ta.0000245974.46709.2e. [PubMed: 18301211].
4. Vaishya R, Singh AP, Hasija R, Singh AP. Treatment of resistant nonunion of supracondylar fractures femur by megaprosthesis. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(7):1137-40. doi: 10.1007/s00167-011-1416-1. [PubMed: 21311865].
5. David SM, Harrow ME, Peindl RD, Frick SL, Kellam JF. Comparative biomechanical analysis of supracondylar femur fracture fixation: Locked intramedullary nail versus 95-degree angled plate. *J Orthop Trauma*. 1997;11(5):344-50. doi: 10.1097/00005131-199707000-00008. [PubMed: 9294798].
6. Hartin NL, Harris I, Hazratwala K. Retrograde nailing versus fixed-angle blade plating for supracondylar femoral fractures: A randomized controlled trial. *ANZ J Surg*. 2006;76(5):290-4. doi: 10.1111/j.1445-2197.2006.03714.x. [PubMed: 16768683].
7. Davison BL. Refracture following plate removal in supracondylar-intercondylar femur fractures. *Orthopedics*. 2003;26(2):157-9. [PubMed: 12597219].
8. Ebraheim NA, Martin A, Sochacki KR, Liu J. Nonunion of distal femoral fractures: A systematic review. *Orthop Surg* 2013;5(1):46-50. doi: 10.1111/os.12017. [PubMed: 23420747]. [PubMed Central: PMC6583155].
9. Schutz M, Muller M, Krettek C, Hontzsch D, Regazzoni P, Ganz R, et al. Minimally invasive fracture stabilization of distal femoral fractures with the LISS: A prospective multicenter study. Results of a clinical study with special emphasis on difficult cases. *Injury*. 2001;32(Suppl 3):SC48-SC54. doi: 10.1016/s0020-1383(01)00183-8. [PubMed: 11888194].
10. Zlowodzki M, Williamson S, Cole PA, Zardiackas LD, Kregor PJ. Biomechanical evaluation of the less invasive stabilization system, angled blade plate, and retrograde intramedullary nail for the internal fixation of distal femur fractures. *J Orthop Trauma*. 2004;18(8):494-502. doi: 10.1097/00005131-200409000-00004. [PubMed: 15475844].
11. Kregor PJ, Stannard JA, Zlowodzki M, Cole PA. Treatment of distal femur fractures using the less invasive stabilization system: Surgical experience and early clinical results in 103 fractures. *J Orthop Trauma*. 2004;18(8):509-20. doi: 10.1097/00005131-200409000-00006. [PubMed: 15475846].
12. Haidukewych G, Sems SA, Huebner D, Horwitz D, Levy B. Results of polyaxial locked-plate fixation of periarticular fractures of the knee. J Bone Joint Surg Am. 2007;89(3):614-20. doi: 10.2106/JBJS.F.00510. [PubMed: 17332111].
13. Vallier HA, Cureton BA, Patterson BM. Factors influencing functional outcomes after distal tibia shaft fractures. *J Orthop Trauma*. 2012;26(3):178-83. doi: 10.1097/BOT.0b013e31823924df. [PubMed: 22198653].
14. Lujan TJ, Henderson CE, Madey SM, Fitzpatrick DC, Marsh JL, Bottlang M. Locked plating of distal femur fractures leads to inconsistent and asymmetric callus formation. *J Orthop Trauma*. 2010;24(3):156-62. doi: 10.1097/BOT.0b013e3181be6720. [PubMed: 20182251].
15. LCP Versus LISS in the treatment of open and closed distal femur fractures: Does it make a difference? *J Orthop Trauma*. 2016;30(6):e212-e216. doi: 10.1097/BOT.0000000000000507. [PubMed: 27218471].
16. Hoffmann MF, Jones CB, Sietsema DL, Tornetta P 3rd, Koenig SJ. Clinical outcomes of locked plating of distal femoral fractures in a retrospective cohort. *J Orthop Surg Res*. 2013;8:43. doi: 10.1186/1749-799X-8-43. [PubMed: 24279475]. [PubMed Central: PMC4222045].
17. Ricci WM, Streubel PN, Morshed S, Collinge CA, Nork SE, Gardner MJ. Risk factors for failure of locked plate fixation of distal femur fractures: An analysis of 335 cases. *J Orthop Trauma*. 2014;28(2):83-9. doi: 10.1097/BOT.0b013e31829e6dd0. [PubMed: 23760176].
18. Moloney GB, Pan T, Van Eck CF, Patel D, Tarkin I. Geriatric distal femur fracture: Are we underestimating the rate of local and systemic complications? *Injury*. 2016;47(8):1732-6. doi: 10.1016/j.injury.2016.05.024. [PubMed: 27311551].
19. Rodriguez EK, Boulton C, Weaver MJ, Herder LM, Morgan JH, Chacko AT, et al. Predictive factors of distal femoral fracture nonunion after lateral locked plating: A retrospective multicenter case-control study of 283 fractures. *Injury*. 2014;45(3):554-9. doi: 10.1016/j.injury.2013.10.042. [PubMed: 24275357].
20. Rodriguez EK, Zurakowski D, Herder L, Hall A, Walley KC, Weaver MJ, et al. Mechanical construct characteristics predisposing to non-union after locked lateral plating of distal femur fractures. *J Orthop Trauma*. 2016;30(8):403-8. doi: 10.1097/BOT.0000000000000593. [PubMed: 27027801].
21. Steinberg EL, Elis J, Steinberg Y, Salai M, Ben-Tov T. A double-plating approach to distal femur fracture: A clinical study. *Injury*. 2017;48(10):2260-5. doi: 10.1016/j.injury.2017.07.025. [PubMed: 28768571].
22. Holzman MA, Hanus BD, Munz JW, O'Connor DP, Brinker MR. Addition of a medial locking plate to an in situ lateral locking plate results in healing of distal femoral nonunions. *Clin Orthop Relat Res*. 2016;474(6):1498-505. doi: 10.1007/s11999-016-4709-3. [PubMed: 26797911]. [PubMed: PMC4868169].
23. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture

and dislocation classification compendium-2018. *J Orthop Trauma*. 2018;32(Suppl 1):S1-S170. doi: 10.1097/BOT.0000000000001063. [PubMed: 29256945].
24. Bergin PF, Tarkin IS, Kempton LB, Sagi HC, Hsu J, Archdeacon MT. Optimizing the Host in Fracture Surgery. *J Orthop Trauma*. 2019;33(Suppl 6):S34-S38. doi: 10.1097/BOT.0000000000001477. [PubMed: 31083147].
25. Brinker MR, O'Connor DP, Monla YT, Earthman TP. Metabolic and endocrine abnormalities in patients with nonunions. *J Orthop Trauma*. 2007;21(8):557-70. doi: 10.1097/BOT.0b013e31814d4dc6. [PubMed: 17805023].
26. Ihle C, Freude T, Bahrs C, Zehendner E, Braunsberger J, Biesalski HK, et al. Malnutrition-An underestimated factor in the inpatient treatment of traumatology and orthopedic patients: A prospective evaluation of 1055 patients. *Injury*. 2017;48(3):628-36. doi: 10.1016/j.injury.2017.01.036. [PubMed: 28132729].
27. Huang TW, Chuang PY, Lin SJ, Lee CY, Huang KC, Shih HN, et al. Teriparatide improves fracture healing and early functional recovery in treatment of osteoporotic intertrochanteric fractures. *Medicine (Baltimore)*. 2016;95(19):e3626. doi: 10.1097/MD.0000000000003626. [PubMed: 27175673]. [PubMed Central: PMC4902515].
28. Johansson T. PTH 1-34 (teriparatide) may not improve healing in proximal humerus fractures. A randomized, controlled study of 40 patients. *Acta Orthop*. 2016;87(1):79-82. doi: 10.3109/17453674.2015.1073050. [PubMed: 26179771]. [PubMed Central: PMC4940597].
29. Babu S, Sandiford NA, Vrahas M. Use of Teriparatide to improve fracture healing: What is the evidence? *World J Orthop*. 2015;6(6):457-61. doi: 10.5312/wjo.v6.i6.457. [PubMed: 26191492]. [PubMed Central: PMC4501931].