ORIGINAL ARTICLE

The Management of Aseptic Non-unions of Distal Femur Fractures with Anatomical Lateral Locking Plates

John Mukhopadhaya[1], Rajeev Ranjan[2], Amit Kumar Sinha[3], Janki Sharan Bhadani[4]

Received on: 30 May 2022; *Accepted on:* 17 August 2022; *Published on:* 30 December 2022

Abstract

Background: Distal femoral non-unions are challenging, and frequently associated with short distal fragments, poor bone stock, and with issues from previous implants.

Materials and methods: A retrospective study of 31 patients admitted with distal femoral non-unions treated using anatomical lateral locking plates. Non-union scores were used. The Knee Society and Neer's scores were used for the comparison of results. The mean follow-up was 39.5 months (from 24 months to 60 months).

Results: Stable union was accomplished in all. There was a significant improvement in the average Neer's score (24 preoperative to 82 post-operatively at final follow-up), the Part 1 Knee Society score from an average of 46 preoperatively to 84 post-operatively, and Part 2 Knee Society score from 36 preoperatively to 80 post-operatively.

Conclusion: Optimal stability, good compression at the non-union site (either by lag screws or a compression device or both), maintaining the axial alignment strictly, freshening of bone ends, using an adequate amount of cortico-cancellous bone graft, respecting the biology along with the correct choice of the implant (including the size) are essential to achieve union at the fracture site.

Clinical significance: Paying attention to the basic principles of management, good contact, stability and maintaining biology is essential in the treatment of non-union.

Keywords: Aseptic non-union, Autologous bone grafting, Compression device, Decortication, Distal femur fracture, Distal femur locking plate, Lateral locking plate, Non-union.

Strategies in Trauma and Limb Reconstruction (2022): 10.5005/jp-journals-10080-1564

Introduction

Fractures of the distal femur have an incidence of 37 per 100,000 person-years.[1] Even with modern methods and implants, the recent data shows rates of non-union percentage ranging 0–30%.[1–5] Yoon et al., in their meta-analysis, found that when using the less-invasive surgical system (LISS), modern-generation locking compression plates (LCP) or retrograde intramedullary nails (RIMN), the average non-union rates are 4–5%.[6] Distal femoral non-union are difficult to treat as these present with short distal fragments, altered regional anatomy, poor bone stock and problems arising from implants used at the initial operation.[7] The United States Food and Drug Administration (FDA) has defined non-unions as fractures that are at least 9 months old and have shown no progressive signs of healing in 3 months.[8] There are cases that fail to unite even after more than one attempt at osteosynthesis. Such cases are considered resistant non-unions.[9,10] Infections, because of being one of the potential causes of failure of surgery, should be ruled out, especially where the previous surgery has been undertaken.[11]

Respecting the biology, stabilisation of the fracture site with revision osteosynthesis, and application of autologous bone graft are of utmost importance in the treatment of non-unions.[12] The literature has reported the use of biological substitutes to augment union; for example, tricalcium phosphate, allograft, bone morphogenetic protein (BMP)-2/7 but these were not used in this study.[11,13,14] We report the outcomes of a series of distal femoral non-unions treated at a single centre with techniques adhering to the principles described above.

[1–4]Department of Orthopaedics, Paras HMRI Hospital, Patna, Bihar, India

Corresponding Author: Janki Sharan Bhadani, C/O John Mukhopadhaya, Department of Orthopaedics, Paras HMRI Hospital, Patna, Bihar, India, e-mail: jsbhadani@gmail.com

How to cite this article: Mukhopadhaya J, Ranjan R, Sinha AK, *et al*. The Management of Aseptic Non-unions of Distal Femur Fractures with Anatomical Lateral Locking Plates. Strategies Trauma Limb Reconstr 2022;17(3):137–143.

Source of support: Nil

Conflict of interest: None

Materials and Methods

This is a retrospective study; the sample consists of patients who presented with distal femoral non-unions. The study was done in a tertiary care referral centre in eastern India. Thirty-two cases satisfying the inclusion criteria had been admitted between June 2006 to December 2019. One patient did not attend a follow-up review leaving 31 cases for review. The institutional ethical committee was informed and informed consent was taken before including patients in our study. The Arbeitsgemeinschaft fur Osteosynthesefragen (AO) trauma classification was used to classify fractures and non-union scores were assessed for each. Outcomes were assessed using Neer's and the Knee Society scoring systems. Comparisons of the preoperative radiograph to serial

post-operative radiographs from subsequent follow-up visits to the hospital were carried out. All distal femoral non-unions, with or without previous surgeries, in skeletally mature subjects were included. Infected non-unions and those patients deemed unfit because of comorbidities or otherwise were excluded.

Preoperative patient status data were obtained from the medical record department (MRD); this included a case sheet of history and clinical examination findings and radiographs and blood investigations from electronic data. The radiographs of the hip and the knee along with radiographs of the non-union were analysed, and computed tomography (CT) scans (if done to confirm non-union or to look for intra-articular involvement) were also assessed.

At surgery in all cases, a prophylactic antibiotic was given within 30 minutes of commencement. A lateral approach or parapatellar approach was used. The previous implant (if present) was removed. Intraoperative cultures were taken from the site of non-union. The site of non-union was debrided of fibrous tissue and the bone ends freshened. Compression was achieved at the fracture site by the use of lag screws or by using the AO (Muller's) compression device[15] and this is followed by stabilisation with a lateral distal femur locking plate (DFLP). Cortico-cancellous bone graft harvested from the ipsilateral iliac crest was placed near the bone ends after decortication of the area (Fig. 1). A C-shaped arm was utilised to check alignment and proper implant placement and positioning. The wound was closed in layers after suction drain placement.

The post-operative protocol of rehabilitation on quadriceps recovery along with continuous passive motion started 48 hours after the operation to facilitate early motion at the knee joint. Removal of the suction drain was on the second post-operative day. Toe-touch weight-bearing mobilisation was started after the first dressing and progressed to partial weight-bearing at 4–6 weeks. Full weight-bearing was allowed by about 3 months depending on the clinical and radiological features. Prophylactic broad-spectrum antibiotics were continued till negative culture reports were available and then discontinued. The patients were followed up at 2 weeks for stitch removal and then at 6 and 12 weeks. Thereafter, the patient review was at 3-months intervals for 1 year and at 6-month intervals thereafter. Appropriate radiographs of the non-union area were taken and compared. Neer's scoring system,16 the Knee Society score 17 and a non-union score18 were used as outcome measures.

Statistical Analysis

Microsoft Office Excel was used for statistical analysis. A paired *t*-test was used for comparison of pre- and post-operative Neer's scores and Knee Society scores.[16,17] Statistical significance was $p < 0.05$.

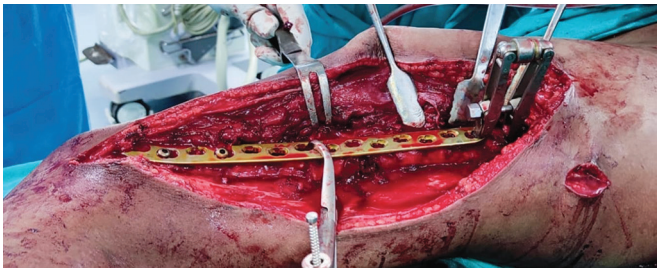


Fig. 1: Distal femur non-union fixation: Freshening on bone ends of non-union site, decortication, bone graft and implant placement (LCP) with compression at the site of non-union using Muller's compression device

Results

Thirty-one patients were operated on between June 2006 and December 2019 and were included in our study. In this sample, 9 (29.03%) patients were in the age range 61–70 years, 8 (25.80%) patients were in the age range 21–30 years, 7 (22.58%) patients were in the age range 31–40 years, 5 (16.12%) patients were in the age range 41–50 years and 2 (6.4%) patients were in the age range 51–60 years. There were 22 males and 9 females with a mean age of 43.09 years (age range, 21–75 years). The right limb was involved in a marginally greater number of patients ($n = 17$) than the left limb ($n = 14$). There was one open fracture; the remaining were closed. Intraoperative cultures were negative for all patients. The cause of fracture was a road traffic accident in the majority of patients (13 patients) with the rest being falls from height (12 patients) and more trivial trauma (6 patients), especially in the elderly population. Non-union scores were used for every patient. The average non-union score was 16.125 (range: 8–21). Two patients were found to have hypertrophic non-unions and bone grafts were not used for those. A total of 10 patients had oligotrophic and 19 had atrophic non-unions; in all those 29 patients, the non-union site was augmented with bone grafts.

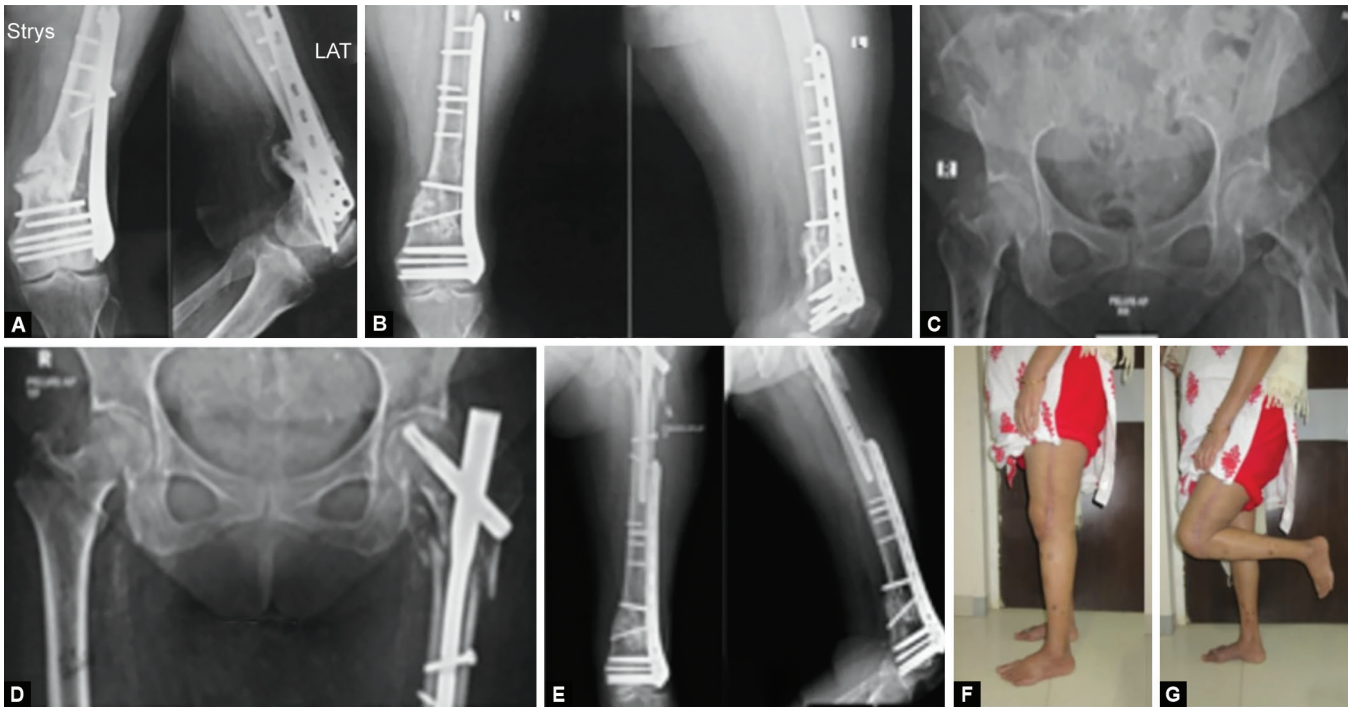
The AO trauma system of fracture classification was used to classify the fractures; there were 33-A2 (1 patient), 33-A3 (16 patients) and 33-C2 (14 patients), respectively. One was an open fracture (Gustilo Anderson type II). Open reduction and internal fixation using a locking plate were done as index surgery in 21 patients [17 patients with only DFLP (Fig. 2), DFLP with proximal femoral nail (PFN) in 1 patient, DFLP with medial plate (Fig. 3) in 1 patient and LCP with cancellous screws in 2 patients], a dynamic condylar screw plate (DCS) in 1 patient (Fig. 4), distal femoral nail (DFN) in 3 patients, external fixation in four patients, skeletal traction in 1 patient and the use of a Thomas splint in 1 patient (Fig. 5).

Of the 31 patients, 3 had surgery 3 times before, 5 had 2 times before and 17 had open reduction internal fixation once. The identifiable risk factors that led to failure in these cases were open fracture, bone loss, poor bone quality, implant failure (loss of reduction, loosening, inappropriate sizing of implant), and inadequate post-operative immobilisation.[18] Six patients who were chronic smokers were counselled to quit smoking. Four patients had diabetes, three patients were morbidly obese and advised dietary restriction and weight reduction and five patients were hypertensive (well controlled).

The non-union site was debrided, tissues sent for microbial culture and sensitivity. Fixation was performed after decortication of the fractur ends at the non-union site with bone graft inserted in 29 cases. The DFLP was used (with compression by either lag screw or the AO-Muller's compression device) for all cases. In one case, the DFLP was applied over the DFN which was present *in situ*. Additional lag screws were applied in 17 cases.

The patients had an average follow-up of 39.5 months (24 months to 60 months). All non-unions had united on radiographs at a mean of 6.42 months (range: 5–12 months) (Table 1). Joint movement measurements showed the average range of motion at knee had improved from 46.5° (10–100°) to 111° (75–130°) at 24 months post-operatively.

The Neer's and Knee Society scores were used for outcomes at 24 months post-operatively. There was a significant improvement in the average Neer's score; the preoperative value of 24 points



Figs 2A to G: A 62-year-old female, 33-A3, had surgery elsewhere (3 times before; primary fixation followed by bone grafting 2 times), (A) Anteroposterior (AP) and lateral radiographs showing non-union at her fracture site with implant failure; (B) The AP and lateral radiographs after revision fixation with bone grafting was done with compression achieved *via* Muller's device and lag screw; (C and D) Radiographs showing intertrochanteric fracture with subtrochanteric extension after 1.5 years, and managed by PFN was done; (E to G) Radiographs and clinical photographs showing union and satisfactory outcome after 31 months

Figs 3A to J: A 51-year-old female with fixation elsewhere (dual plating) referred to us after 16 months of index surgery with stiff knee the surgeon removed the lateral plate (elsewhere). (A) First X-ray available showing distal femur fracture; (B) X-ray after primary surgery elsewhere showing fixation using dual plate; (C and D) X-ray at 12 months, when patient underwent second surgery for stiff knee, and lateral plate removal was done; (E) The medial plate broke and patient presented to us with pain and inability to bear weight after 16 months of index surgery; (F) Immediate post-operative radiographs after revision fixation with bone grafting and compression achieved with one lag screw; (G) Radiographs at 8-months follow-up; (H to J) Radiographs and clinical photographs at 20 months follow-up showing satisfactory outcome

(range: 16–44 points) improved to 82 points post-operatively (range: 72–96). This was highly significant ($p < 0.00001$) (Table 2). The Part 1 Knee Society score also improved from an average of 46 points (range: 36–68) preoperatively to 84 points (range: 74–93) post-operatively. Eight patients had scores in the range of 70–79 thereby indicating a good outcome of the surgery while the remaining 23 patients scored above 80 points thereby indicating an excellent outcome of surgery. The difference between pre post-operative scores was highly significant ($p < 0.00001$) (Table 3). The Knee Society function score improved from a mean of 36 points (15–45 points) to 80 points (70–90 points) post-operatively. A total of 11 patients scored in the range of 70–79 thereby indicating a

Figs 4A to I: A 75-year-old male patient with 2-year-old non-union supracondylar fracture left femur presented with (A) Anteroposterior (AP) and lateral radiographs after trauma; (B) AP and lateral radiographs after index surgery; (C) AP and lateral radiographs showing non-union after implant (DCS) failure at presentation to us after 2 years of index surgery; (D) Immediate post-operative AP and lateral radiographs after implant removal, decortication, bone grafting fixation using DFLCP, and done; (E) AP and lateral radiographs showing union at 5.5 months; (F to I) Radiographs and clinical pictures showing satisfactory outcome after 2 years and 6 months

good outcome while scores of the remaining 20 patients were above 80 points indicating excellent outcomes ($p < 0.00001$) (Table 3).

The complications included haematoma collections seen in two patients. Both were explored and debrided under anaesthesia. Superficial infection was encountered in one patient on the 10th post-operative day which was managed with wound debridement and antibiotics. There were no deep venous thromboses or malunions. One patient had an ipsilateral fracture of the shaft of the femur after another fall 18 months post-surgery; this was managed with plating. Another patient sustained an intertrochanteric fracture of the same limb also18 months post-surgery and this was managed with a PFN.

Discussion

The treatment of distal femoral non-unions is difficult with the objectives of restoration of length, axis and rotation and keeping a congruous knee joint of the affected extremity. In this retrospective series, 31 subjects were managed surgically with revision osteosynthesis using an LCP. Bone graft augmentation harvested from the ipsilateral iliac crest was done in cases of atrophic and oligotrophic types of non-union (29 patients). Proper implant selection is important and should be able to provide both stability as well as the flexibility to favour osteosynthesis at the site of non-union. Locking plates act as a fixed-angle single-plate screw configuration where the pull-out strength is significantly more than when compared to single-screw pull-out strength in a non-locking plate.[6] The locking plates were used with compression and the use of conventional and locking screws were dependent upon the quality of bone and fracture pattern. The use of a longer plate construct is one of the factors a surgeon may choose for achieving union.[19] In this series, a careful selection of the length of the plate, screw–plate density, implant material (titanium plate was used) and appropriate reduction and compression at the site of non-union were made with the aim of avoiding failure.[20,21] The literature supports titanium as more of a biocompatible and flexible material with Young's modulus comparable to the bone as opposed to stainless steel.[11,21]

There were a high number of patients ($n = 20$) who were aged 21–50 years in this sample, with a large proportion of males; this is in accordance with the findings of another study done by Martinet et al.[22] who reviewed 2,165 distal femoral fractures (between 1980 and 1989) comprising 1,051 women and 1,114 men. Lee et al.,[23] in a similar study, reported a mean age of 42 years (range: 18–82 years). The results suggest distal femoral fractures are more common in the young. Related studies[4,7] have shown a higher number of males as compared to females, consistent with the findings in our study. The most common cause of the primary fracture for our patients was a road traffic accident ($n = 13$), and a fall from height ($n = 12$) was the second most common cause and trivial trauma ($n = 6$; in the elderly population in the age range 61–70 years) was the third most common trauma. A similar pattern was reported in earlier studies[7] suggesting modernisation may have led to increases in high-energy trauma accidents.

The average time to union was 6.68 months for all non-unions in our series (5–12 months). In another study by Ryan et al.[24] the average time for union with locking plates was 6 months (3–14 months) vs 7 months (3–15 months) in an external fixation group. In a study by Gardner et al.,[25] 31 patients with a distal femoral

Figs 5A to H: (A) A 42-year-old man managed conservatively (elsewhere) presenting with non-union of distal femur fracture after 11 months; (B) Immediate post-operative radiographs after ORIF with DFLP, bone grafting with compression achieved across fracture site; (C) Radiographs showing union at 6 months follow-up; (D to H) Radiographs and clinical photographs at 30-months follow-up showing satisfactory outcome

Table 1: Average duration of union in months

Time to union (months)	*Number of cases*
5	11
6	8
7	6
8	3
9	2
12	1

Table 2: Distribution of patients as per Neer's score

Neer's score	*Number of patients*	*Percentage*
>85 (excellent)	11	35.48
70–85 (satisfactory)	20	64.51
55–69 (unsatisfactory)	Nil	–
<55 (failure)	Nil	–

Table 3: Distribution of patients as per Knee Society score

Knee Society score (Part 1)			*Knee Society score (Part 2)*	
Total score	*Number of patients*	*Percentage*	*Number of patients*	*Percentage*
80–100 (excellent)	23	74.19	20	64.51
70–79 (good)	8	25.80	11	35.48
60–69 (fair)	Nil	–	Nil	–
<60 (poor)	Nil	–	Nil	–

non-union were treated between 1992 and 2002, and were assessed for their clinical and radiographic outcomes. The mean age of patients studied was 57.6 years and the average follow-up time was 41.5 months. At the last follow-up, the rate of union was 97%, and the time to healing was 15.9 weeks. In our study, the average follow-up was 39.5 months and the average time to union was 28.6 weeks. In another study done by Singh et al.,[26] 14 patients with clinically and radiologically defined non-union at the distal femoral fracture site were treated with the addition of a medially placed locked plate with autologous graft augmentation. The average time to union was 5 months and their findings consistent with our study. The study by Kanakeshwar et al.[10] was undertaken with 22 patients and the average time union time was 6.2 months (5–8 months) (Table 4).

The average range of flexion at the knee improved from a mean of 46.5° (range, 10–100°) preoperatively to 111° (range, 75–130°) post-operatively as measured at 24 months follow-up. In a study by Haidukewych et al.,[27] the mean range of motion at the knee was 1–96°. In a study by Wang and Weng,[28] the average range of flexion at the knee improved from 45° to 73° after operation. In another study by Bellabarba et al.,[29] improvement in average flexion of motion was from 92° to 110°.

We aimed to improve outcome and union by establishing complete stability, good compression at the non-union sites using lag screws or a compression device or both, freshening the bone ends, decortication of bone near the non-union site and placing

Table 4: Comparison of results

Study	*Number of cases*	*Mean follow–up*	*Average union time*	*Implant failure*
Wang and Weng[28]	13	34 months	5 months = 21.7 weeks	None
Gardner et al.[25]	31	41.5 months	15.9 weeks	1
Singh et al.[26]	14	2.1 years	5 months = 21.7 weeks	None
Kanakeshwar et al.[10]	22	24 months	6.2 months = 26.9 weeks	1
Present study	31	39.5 months	6.6 months = 28.6 weeks	None

autogenous bone graft harvested from the ipsilateral iliac crest. Axial alignment was strictly maintained.

The limitations of this work include the sample being from a single centre and the retrospective design. All cases were performed by a team led by an experienced surgeon and hence the results cannot be generalised. We considered the small number of patients with distal femur non-unions; thus, published this report which is one of the largest single-centre series.

Conclusion

Success with non-union treatment arises from following the principles of internal fixation, respecting the tissue biology, restoring axial alignment, maintaining the structural support through contact and compression between the fracture ends, the optimal implant and augmentation of healing through autogenous bone grafts.

Clinical Significance

Implant choice alone will not determine union for distal femoral fractures. In this series, 63% of non-unions were treated primarily with a distal femoral locking plate. The same implant was used for treating the non-union but, in addition, attention to the other important variables determining success, as listed above, can make the difference between success and failure.

Orcid

John Mukhopadhaya https://orcid.org/0000-0001-9185-6274
Amit Kumar Sinha https://orcid.org/0000-0002-1938-8717
Janki Sharan Bhadani https://orcid.org/0000-0002-3329-8355

References

1. Zlowodzki M, Bhandari M, Marek DJ, et al. Operative treatment of acute distal femur fractures: Systematic review of 2 comparative studies and 45 case series (1989 to 2005). J Orthop Trauma 2006;20(5):366–371. DOI: 10.1097/00005131-200605000-00013.
2. Nayak RM, Koichade MR, Umre AN, et al. Minimally invasive plate osteosynthesis using a locking compression plate for distal femoral fractures. J Orthop Surg (Hong Kong) 2011;19(2):185–190. DOI: 10.1177/230949901101900211.
3. Rodriguez EK, Boulton C, Weaver MJ, et al. Predictive factors of distal femoral fracture nonunion after lateral locked plating: A retrospective multicentre case–control study of 283 fractures. Injury 2014;45(3):554–559. DOI: 10.1016/j.injury.2013.10.042.
4. Henderson CE, Kuhl LL, Fitzpatrick DC, et al. Locking plates for distal femur fractures: Is there a problem with fracture healing? J Orthop Trauma 2011;25(Suppl. 1):S8–S14. DOI: 10.1097/BOT.0b013e3182070127.
5. Dyke BV, Colley R, Ottomeyer C, et al. Effect of blocking screws on union of infraisthmal femur fractures stabilized with a retrograde intramedullary Nail. J Orthop Trauma 2018;32(5):251–255. DOI: 10.1097/BOT.0000000000001119.
6. Yoon BH, Park IK, Kim Y, et al. Incidence of nonunion after surgery of distal femoral fractures using contemporary fixation device: A meta-analysis. Arch Orthop Trauma Surg 2021;141(2):225–233. DOI: 10.1007/s00402-020-03463-x.
7. Ebraheim NA, Martin A, Sochacki KR, et al. Nonunion of distal femoral fractures: A systematic review. Orthop Surg 2013;5(1):46–50. DOI: 10.1111/os.12017.
8. Brinker MR. Nonunions: Evaluation and treatment. In: Trafton PG, editor. Skeletal Trauma: Basic Science, Management, and Reconstruction, 3rd edition. Philadelphia: W.B. Saunders; 2003, p.507–604.
9. Vaishya R, Singh AP, Hasija R, et al. Treatment of resistant nonunion of supracondylar fractures femur by megaprosthesis. Knee Surg Sports Traumatol Arthrosc 2011;19(7):1137–1140. DOI: 10.1007/s00167-011-1416-1.
10. Kanakeshwar RB, Jayaramaraju D, Agraharam D, et al. Management of resistant distal femur non-unions with allograft strut and autografts combined with osteosynthesis in a series of 22 patients. Injury 2017;48(Suppl. 2):S14–S17. DOI: 10.1016/S0020-1383(17)30488-6.
11. Maheshwari P, Maheshwari P. Nonunion distal femur fracture: Causes and management Options. Trauma Int 2016;1(2):28–33. DOI: 10.13107/ti.2016.v02i01.017.
12. Emara KM, Diab RA, Emara AK. Recent biological trends sin management of fracture non-union. World J Orthop 2015;6(8):623–628. DOI: 10.5312/wjo.v6.i8.623.
13. de Grado FG, Keller L, Idoux–Gillet Y, et al. Bone substitutes: A review of their characteristics, clinical use, and perspectives for large bone defects management. J Tissue Eng 2018;9:2041731418776819. DOI: 10.1177/2041731418776819.
14. Wang W, Yeung KWK. Bone grafts and biomaterials substitutes for bone defect repair: A review. Bioact Mater 2017;2(4):224–247. DOI: 10.1016/j.bioactmat.2017.05.007.
15. Harris NH. Clinical experience with the Müller compression device. Proc R Soc Med 1965;58(11 Part 1):879–882. PMID: 5851529.
16. Schmidt–Rohlfing B, Pfeifer R, Kaneshige J, et al. Scoring systems for outcome after knee injuries. Injury 2011;42(3):271–275. DOI: 10.1016/j.injury.2010.11.059.
17. Insall JN, Dorr LD, Scott RD, et al. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;(248):13–14. PMID: 2805470.
18. Calori GM, Phillips M, Jeetle S, et al. Classification of non-union: Need for a new scoring system? Injury 2008;39(Suppl. 2):S59–S63. DOI: 10.1016/S0020-1383(08)70016-0.
19. Weaver MJ, Chaus GW, Masoudi A, et al. The effect of surgeon-controlled variables on construct stiffness in lateral locked plating of distal femoral fractures. BMC Musculoskelet Disord 2021;22(1):512. DOI: 10.1186/s12891-021-04341-2.
20. Bel JC. Pitfalls and limits of locking plates. Orthop Traumatol Surg Res 2019;105(1S):S103–S109. DOI: 10.1016/j.otsr.2018.04.031.
21. Barber CC, Burnham M, Ojameruaye O, et al. A systematic review of the use of titanium versus stainless steel implants for fracture fixation. OTA Int 2021;4(3):e138. DOI: 10.1097/OI9.0000000000000138.
22. Martinet O, Cordey J, Harder Y, et al. The epidemiology of fractures of the distal femur. Injury 2000;31(3):62–63. DOI: 10.1016/s0020-1383(00)80034-0.
23. Lee JA, Papadakis SA, Moon C, et al. Tibial plateau fractures treated with the less invasive stabilisation system. Int Orthopaedic 2007;31(3):415–418. DOI: 10.1007/s00264-006-0176-x.

24. Ryan JK, Arthur LM, Craig SR, et al. Treatment of bicondylar tibia plateau fractures using locked plating versus external fixation. Orthopedics 2009;32:559–570. DOI: 10.3928/01477447-20090624-11.
25. Gardner MJ, Toro–Arbelaez JB, Harrison M, et al. Open reduction and internal fixation of distal femoral nonunions: Long-term functional outcomes following a treatment protocol. J Trauma 2008;64(2): 434–438. DOI: 10.1097/01.ta.0000245974.46709.2e.
26. Singh A, Vohra R, Thorat B, et al. Outcomes of distal femur nonnunion following lateral locked plating treated with an addition of a medial locking plate and autogenous bone graft. Orthop Spo Med Op Acc J 2020;4(3):389–397. DOI: 10.32474/OSMOAJ.2020.04.000187.
27. Haidukewych GJ, Berry DJ, Jacofsky DJ, et al. Treatment of supracondylar femur nonunions with open reduction and internal fixation. Am J Orthop (Belle Mead NJ) 2003;32(11):564–567. PMID: 14653489.
28. Wang JW, Weng LH. Treatment of distal femoral nonunion with internal fixation, cortical allograft struts, and autogenous bone-grafting. J Bone Joint Surg Am 2003;85(3):436–440. DOI: 10.2106/00004623-200303000-00006.
29. Bellabarba C, Ricci WM, Bolhofner BR. Indirect reduction and plating of distal femoral nonunions. J Orthop Trauma 2002;16(5):287–296. DOI: 10.1097/00005131-200205000-00001.