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# Medial and lateral dual plating of native distal femur fractures: a systematic literature review

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**Abstract**

**Introduction:** Lateral locked plating (LLP) development has improved outcomes for distal femur fractures. However, there is still a modest rate of nonunion in fractures treated with LLP alone, with higher nonunion risk in high-energy fractures, intra-articular involvement, poor bone quality, severe comminution, or bone loss. Several recent studies have demonstrated both the safety and the biomechanical advantage of dual medial and lateral plating (DP). The purpose of this study was to evaluate the clinical outcomes of DP for native distal femoral fractures by performing a systematic review of the literature.

**Methods:** Studies reporting clinical outcomes for DP of native distal femur fractures were identified and systematically reviewed. Publications without full-text manuscripts, those solely involving periprosthetic fractures, or fractures other than distal femur fractures were excluded. Fracture type, mean follow-up, open versus closed fracture, number of bone grafting procedures, nonunion, reoperation rates, and complication data were collected. Methodologic study quality was assessed using the Coleman methodology score.

**Results:** The initial electronic review and reverse inclusion protocol identified 1484 publications. After removal of duplicates and abstract review to exclude studies that did not discuss clinical treatment of femur fractures with dual plating, 101 potential manuscripts were identified and manually reviewed. After final review, 12 studies were included in this study. There were 199 fractures with average follow-up time of 13.72 months. Unplanned reoperations and nonunion occurred in 19 (8.5%) and 9 (4.5%) cases, respectively. The most frequently reported complications were superficial infection (n = 6, 3%) and deep infection (n = 5, 2.5%) postoperatively. Other complications included delayed union (n = 6, 3%) not requiring additional surgical treatment and knee stiffness in four patients (2%) necessitating manipulation under anesthesia or lysis of adhesions. The average Coleman score was 50.5 (range 13.5–72), suggesting that included studies were of moderate-to-poor quality.

**Conclusions:** Clinical research interest in DP of distal femoral fractures has markedly increased in the past few decades. The current data suggest that DP of native distal femoral fractures is associated with favorable nonunion and reoperation rates compared with previously published rates associated with LLP alone. In the current review, DP of distal femoral fractures was associated with acceptable rates of complications and generally good functional outcomes. More high-quality, directly comparable research is necessary to validate the conclusions of this review.

**Keywords:** distal femur fracture; dual-plating; systematic review

## 1. Introduction

Lateral locked plating (LLP) is a popular fixation method for distal femoral fractures, particularly in injuries with distal involvement or poor bone quality at risk for failure with treatment using a retrograde intramedullary nail. Although LLP has improved outcomes relative to prior laterally based implants, treatment of distal femoral fractures with LLP is associated with moderate nonunion rates, with a recent review of the literature demonstrating nonunion rates for native distal femur fractures from 0% to 19% across published studies.[1]

Prior research has highlighted at-risk fracture types for failure of fixation with LLP. Molina et al demonstrated that comminution was an independent risk factor for fracture nonunion.[2] Similarly, Henderson et al[3] demonstrated higher rates of nonunion across Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (OTA/AO) 33.A3, C2, and C3 fracture types. To address persistent failures associated with these injuries, several authors have advocated for additional stabilization with a medial plate in fractures with complex intra-articular involvement, high-energy mechanisms, poor bone quality, or severe metaphyseal comminution or bone loss.[4–6] As a consequence, research interest in medial and lateral dual plating (DP) of distal femur fractures has increased dramatically, with 31 manuscripts published from 2015 to 2021 compared with only seven manuscripts published from 2000 to 2014 (Fig. 1).

Several recent biomechanical studies have demonstrated increased stiffness and decreased fracture motion characteristics for DP relative to LLP, as well as compared with reamed intramedullary nails and plate–nail combinations.[4,7–12] These biomechanical characteristics may be advantageous in the setting of early weight-

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bearing for osteoporotic fractures and for comminuted, high-energy injuries without load sharing potential. In addition, despite traditional concerns regarding dysvascularity associated with a separate medial approach to the distal femur, multiple recent anatomic and imaging studies have shown that there is a relatively wide safe zone for minimally invasive medial plate application without significant vascular disruption.[5,12–16]

Existing clinical research on medial and lateral DP of the distal femur has been primarily limited to small case series and retrospective comparative studies. Lodde et al[17] recently performed a systematic review of DP for femoral fractures. However, the authors focused on several types of injuries and plate configurations. No systematic review has focused in detail on clinical outcomes associated with medial and lateral DP of native distal femur fractures. Given the biomechanical rationale and anatomic safety for DP demonstrated in recent research, the purpose of this study was to perform a systematic review of the literature evaluating clinical studies investigating medial and lateral plating for native distal femoral fractures.

## 2. Methods

We performed a systematic review of the literature in accordance with the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement.[18] English language studies were identified in PubMed and Scopus from inception to March 2021. The search strategy was identical for both databases and included the following search terminology: "distal femur AND dual plating" OR "distal femur AND medial plate" OR "distal femur AND double plate" OR "femur fracture AND medial plate" OR "femur fracture AND dual plate" OR "femur fracture AND double plate" OR "periprosthetic distal femur AND medial plate" OR "periprosthetic distal femur AND dual plate" OR "periprosthetic distal femur AND double plate". The review was registered in PROSPERO, an international prospective register of systematic reviews funded by the National Institute of Health Research, on March 11, 2021 (ID# 242303).

Abstracts from initial electronic search output were independently reviewed by 2 authors (A.J.H., G.J.D.) to identify all studies related to DP of the distal femur. Studies identified as potentially relevant during abstract review were then reviewed in full-text manuscript format. Manuscripts were included in the final review if they addressed clinical outcomes for medial and lateral dual plating of native distal femur fractures. Studies solely involving periprosthetic fracture were excluded. Studies that discussed DP of other types of femur fractures (eg, femoral shaft) and plate configurations other than medial/lateral were also excluded. Studies that included both native and periprosthetic fracture were included in the final analysis if most (>50%) of the treated fractures were native. Inclusion was by reviewer consensus. If discrepancies arose between reviewers, a third author (J.M.H.) was consulted to make a final inclusion determination. A reverse inclusion protocol was completed by a single author (D.C.O.) through review of the bibliographies of included studies to identify additional relevant literature.

For included studies, data were aggregated including number of participants, fracture type, mean follow-up time, number of open versus closed fractures, number of bone grafting procedures, nonunion and reoperation rates, and complication data. For the purposes of the review, nonunion was defined as explicitly stated cases of nonunion or patients who underwent unplanned reoperation for bone grafting. Delayed union without need for reoperation (eg, fibrous stable asymptomatic partial nonunion) was not included in the definition of nonunion. The definition of planned reoperation was limited to patients who returned to the operating room (OR) for bone grafting with an induced membrane technique. Unplanned reoperation was defined as any reported return to the OR outside of planned bone grafting as discussed above. Two study authors (D.C.O., A.J.H.) assessed methodologic study quality using the Coleman methodology score, a 10-part scoring system with a maximum score of 100 designed to evaluate quality in clinical studies.[19] The Coleman score is a well-established tool to assess the methodological quality of the included papers.[20–22]

## 3. Results

The initial electronic review and reverse inclusion protocol identified 1484 publications. After removal of duplicates, 1001 abstracts were reviewed, and 101 manuscripts were identified as potentially relevant. Full-text manuscripts were reviewed for these studies. After final review, 12 studies were included in the

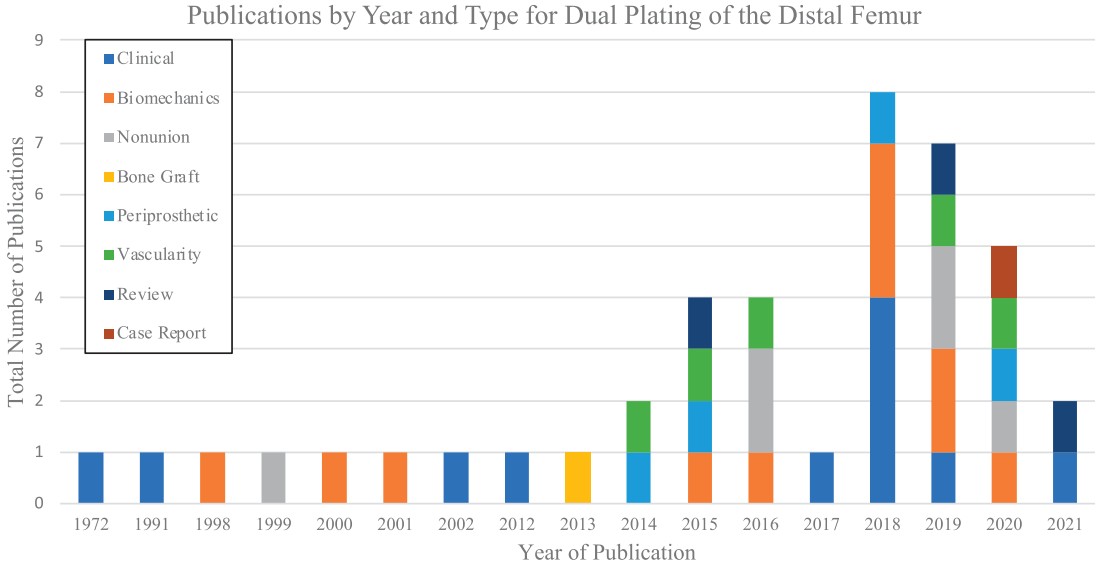


**Figure 1.** Publications by year and type for dual plating of the distal femur over the past 5 decades. Research interest in dual plating of distal femoral fractures has increased significantly in the past few decades.

final protocol because they provided clinical data on medial and lateral dual plating of native distal femoral fractures (Fig. 2).

Eleven of 12 included studies were published within the last 10 years (Table 1). Eight of 12 studies were small case series describing outcomes for medial and lateral dual-plated distal femoral fractures.[23–30] Four studies compared clinical outcomes between DP and LLP.[6,7,31,32] Two studies included a minority of periprosthetic fractures in a combined cohort with native distal femur fractures.[6,27] In total, there were 199 fractures included in the review with an average follow-up time of 14 months. Mean age varied widely across studies. Sixty percent of included patients were female. Of included fractures, 45 (22.6%) were open injuries. Most of the studies limited inclusion to fractures with complete articular involvement (OTA/AO 33.C) and/or complex metaphyseal comminution (OTA/AO 33.A3), although the individual inclusion and exclusion criteria varied by study. Forty-two fractures were treated with bone grafting during the index procedure, and 26 fractures were treated with an induced membrane technique. Four studies performed acute bone grafting in most of the cases, and 2 studies performed staged bone grafting in all cases using the Masquelet technique. Planned reoperations occurred in 26 patients (13.1%). All planned reoperations were staged bone grafting as part of an induced membrane (Masquelet) technique. Unplanned reoperations and nonunion occurred in 19 (8.5%) and 9 (4.5%) cases, respectively. The other causes of unplanned reoperation outside of nonunion were knee stiffness requiring internal lysis of adhesions or knee manipulation under anesthesia and infection.

Sixty-seven percent of included studies reported complications outside of nonunion (Table 2). The most frequently reported complications were infection and delayed union. While most studies included functional outcome data, reporting metrics varied considerably across studies (Table 1). As such, direct comparison of functional outcomes or aggregation of outcome data was not possible across studies. Overall, the studies included in the review reported generally favorable functional outcomes, although knee stiffness was a commonly cited functional limitation.

All studies in the included review were evaluated for clinical quality using the Coleman methodology score. The average Coleman score was 50.5 (range 13.5–72) suggesting that included studies were of moderate-to-poor quality. Most of the studies scored poorly in study size (mean score 1.2 vs. max score 10) and duration of follow-up (mean score 1.6 vs. max score 5). In addition, the retrospective nature of most studies prevented included studies

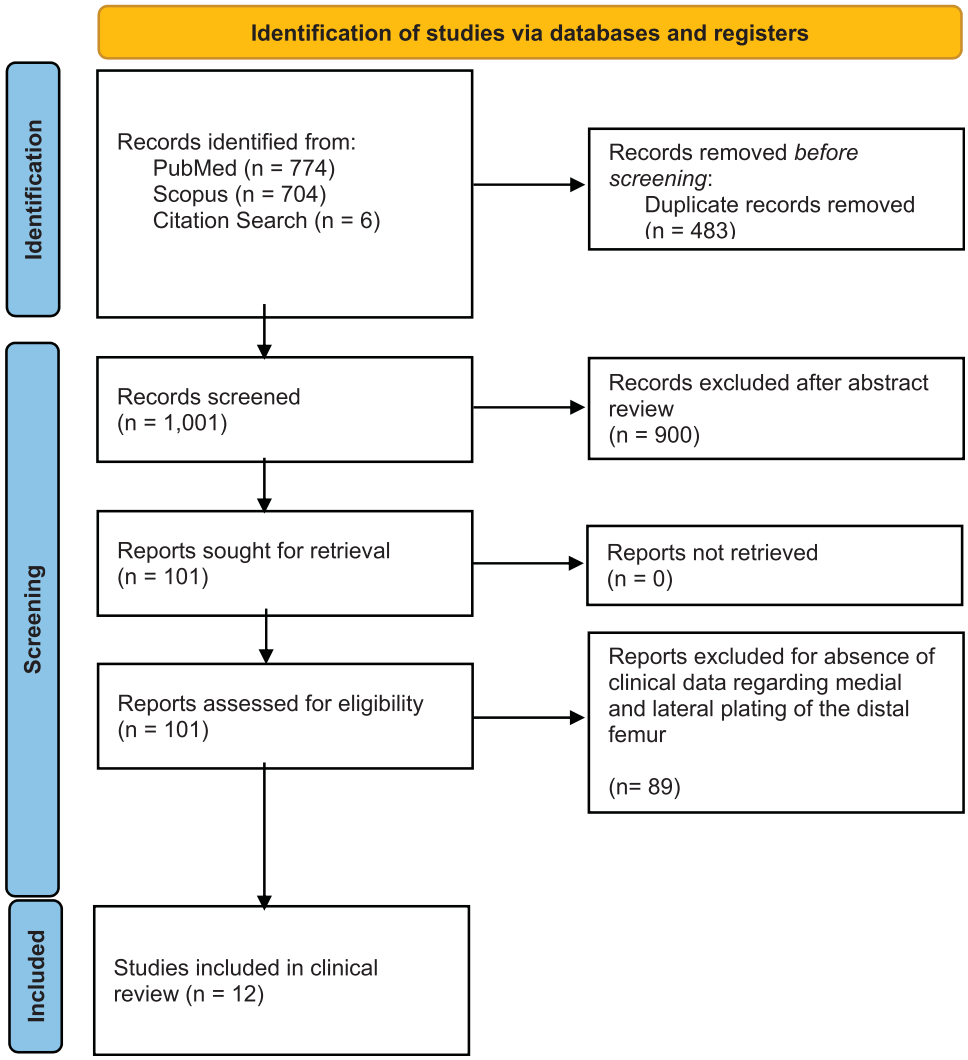


**Figure 2.** PRISMA flow diagram. 1001 unique records were screened, and 12 relevant clinical studies were identified for inclusion in the final analysis.

**TABLE 1**

**Patients' Demographic, Fracture Classification, Description of Surgical Technique, Reported Outcome Including Complications, and Coleman Methodology Score of the Included Studies**

| Publication | N | OTA/AO Fracture Classification | Mean Follow-Up (mo) | Age (Range) | % Male | Primary Procedures | Index Procedures For Existing Nonunion | % Closed Fractures | Surgical Approach | Index Bone Grafting | Planned Reoperation (n) | Unplanned Reoperation (n) | Nonunion (n) | Reported Outcomes | Complications Reported | Coleman Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sanders et al, 1991 [27] | 9 | 33-C2; 33-C3 intraoperative varus collapse | 26 | 39 (21–75) | 33 | 9 | 0 | 44 | Lateral approach to femur plus medial subvastus or TTO | All cases | 0 | 0 | 0 | Five good and 4 fair results, knee ROM biggest limiting factor (5 patients had knee ROM 90 degrees or less; no patient had greater than 110 degrees of knee flexion) | No | 54 |
| Khalil and Ayoub, 2012[15] | 12 | 33-C3 | 14 | 34 (22–44) | 67 | 12 | 0 | 100 | Modified Olerud (TTO with extensor mechanism reflection) | All cases | 0 | 0 | 0 | 2 excellent, 5 good, 3 fair, 2 poor. Fair and poor cases were related to poor knee ROM. Average knee ROM 0–112.4 degrees. | Yes | 62 |
| Dugan et al, 2013[7] | 15 | 33-C2; 33-C3 | NR | 41 (16–75) | 53 | 15 | 0 | 0 | Initial surgery with lagging of articular block, lateral locked fixation, antibiotic bead pouch, and plastics closure. Definitive reconstruction with lateral plate retention, bone graft, and medial plating. Iliac crest most commonly used bone graft. BMP2 was used. Average time to reconstruction 3.6 mo (1–6 mo) | All cases with staged Masquelet technique | 15 | 0 | 0 | Average ROM arc 2–88 degrees. Extension range: 0–10 degrees. Flexion range: 40–120 degrees. Tibiofemoral angle 4.8 degrees (−1 to 11 degrees) postoperatively. Tibiofemoral angle 5.0° (−6 to 5 degrees) at final follow-up. Average change in tibiofemoral angle was 0.46 degrees (−2 to 5 degrees). | Yes | 45 |
| Steinberg et al, 2017 [31] | 32 | 33-A; 33-C (8 periprosthetic) | 12 | 76 (44–101) | 19 | 30 | 2 | 97 | Separate medial and lateral approaches | No | 0 | 2 | 1 | One case of coronal plane malunion at 8 degrees of valgus. Knee extension 0–20 degrees. Knee flexion 85–120 degrees. | Yes | 52 |

(*continued on next page*)

TABLE 1 (*continued*)

| Publication | N | OTA/AO Fracture Classification | Mean Follow-Up (mo) | Age (Range) | % Male | Primary Procedures | Index Procedures For Existing Nonunion | % Closed Fractures | Surgical Approach | Index Bone Grafting | Planned Reoperation (n) | Unplanned Reoperation (n) | Nonunion (n) | Reported Outcomes | Complications Reported | Coleman Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imam et al, 2018[13] | 16 | 33-C3 | 12 | 36 (18–59) | 69 | 16 | 0 | 100 | Extensile anterior approach | 10/16 | 0 | 2 | 1 | 4 excellent, 7 good, 3 fair, 2 poor. No residual deformity present. Knee flexion: 1 patient less than 90 degrees, 11 patients 90–120 degrees, 4 patients greater than 120 degrees. | Yes | 60 |
| Swentik et al, 2018 [32] | 11 | 33-A3; 33-C2; 33-C3 | NR | 53 (NR) | 55 | 11 | 0 | 9 | Open fracture debridement within 24 h. Definitive fixation once patient stable. Lateral locking fixation with medial plate supplementation using subvastus approach. | All cases with staged Masquelet technique | 11 | 2 | 2 | Average arc of motion 106 degrees. Total arc of motion >125 degrees in 3. 100–124 degrees in 3. 75–99 degrees in 1. 50–74 degrees in 1. Average tibiofemoral angle was 6.4 degrees (5.7–9.0°) valgus. | Yes | 55 |
| Bai et al, 2018[1] | 12 | 33-C | 16 | NR | 50 | 12 | 0 | 8 | Fractures were indicated for dual plating with a positive varus stress test intraoperatively once LCL injury had been excluded. Medial and lateral plating using a locked Zimmer or Synthes lateral plate with a standard compression plate medially. | 11/12 | 0 | 0 | 0 | 4 excellent, 5 good, 2 fair, 1 poor | No | 14 |
| Metwaly et al, 2018 [21] | 23 | 33-A3; 33-C | 14 | 70 (61–80) | 17 | 23 | 0 | 100 | Medial or lateral parapatellar based on the proximal most fracture apex | No | 0 | 4 | 4 | EQ-5D-5 L mean 83.8 (72–92). Knee ROM within 3–5 degrees of contralateral side in | Yes | 66 |

(*continued on next page*)

TABLE 1 (*continued*)

| Publication | N | OTA/AO Fracture Classification | Mean Follow-Up (mo) | Age (Range) | % Male | Primary Procedures | Index Procedures For Existing Nonunion | % Closed Fractures | Surgical Approach | Index Bone Grafting | Planned Reoperation (n) | Unplanned Reoperation (n) | Nonunion (n) | Reported Outcomes | Complications Reported | Coleman Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | all cases. No loss of reduction noted. | | |
| Zhang et al, 2018[35] | 14 | 33-A2; 33-A3 | 12* | 59 (NR) | 36 | 14 | 0 | 100 | Separate medial and lateral approaches. Locked plating laterally. | No | 0 | 0 | 0 | 12 mo outcomes: VAS pain = 0.25; knee ROM = 125 degrees; Neer knee score 86.86. | No | 72 |
| Bologna et al, 2019 [4] | 8 | 33-C2; 33-C3 (2 periprosthetic) | 12 | 67 (55–78) | 10 | 8 | 0 | 88 | Separate medial and lateral approaches. Locked plating both medially and laterally. | No | 0 | 1 | 0 | Mean knee ROM 90 degrees at final follow-up | Yes | 42 |
| Kochish et al, 2020 [17] | 15 | 33-A3; 33-C2; 33-C3 | 6* | 51 (23–70) | 60 | 15 | 0 | 87 | Separate medial and lateral incisions with MIPO used medially. | No | 0 | 2 | 1 | Mean knee ROM 96 degrees (40–125 degrees). At 12 mo: KSS scale—8/11 (72%) good or excellent and Lysholm scale—8/11 (72%) good or excellent | Yes | 40 |
| Liu et al, 2021[18] | 32 | 33-A3; 33-C2; 33-C3 | 14 | 61 (NR) | 38 | 32 | 0 | 100 | Separate medial and lateral incisions with locked fixation distally for both medial and lateral plates. | No | 0 | 0 | 0 | Statistically better reduction quality for coronal angulation, sagittal angulation, and translation relative to lateral plating alone. Kolment score was excellent or good in 25/32 (78%) patients at final follow-up. | No | 46 |

* Minimum follow-up.

BMP = bone morphogenetic protein; EQ-5D-5L = EuroQol-5 dimensions; KSS = Knee Society Score; LCL = lateral collateral ligament; MIPO = minimally invasive plate osteosynthesis; NR = not reported; ROM = range of motion; TTO = tibial tubercle osteotomy; VAS = visual analog scale.

**TABLE 2**

**Reported Complications**

| Publication | N (%) |
|---|---|
| Studies reporting complications | 8 (66.7) |
| Superficial infection | 6 (3.0) |
| Delayed union not requiring return to OR | 6 (3.0) |
| Deep infection | 5 (2.5) |
| Knee adhesions requiring manipulation or lysis | 4 (2.0) |
| Heterotopic ossification | 2 (1.0) |
| Delayed wound healing | 2 (1.0) |
| Deep vein thrombosis | 1 (0.5) |

Two-thirds of studies reported complications associated with medial and lateral dual plating of native distal femoral fractures. The most common complications outside of nonunion were infection and knee stiffness.

from scoring in domains such as "written assessment." "investigator independent of surgeon," and "recruitment rate reported."

## 4. Discussion

The major findings of this systematic review are low aggregate rates of nonunion (less than 5%) and unplanned reoperation (less than 10%) for native distal femoral fractures treated with medial and lateral dual plating. Few similar studies currently exist in the literature. One prior systematic review recently evaluated outcomes associated with dual plating of distal femur fractures.[17] The review documented 108 native distal femur fractures treated with dual plating in 6 separate studies and found a nonunion rate of 9.8%. In addition, complication rates for infection were higher in the previous review (8.3% vs. 3.0%). Five of the 6 studies included in the review were also included in this study. However, the review differs from this study in multiple respects. Most importantly, the authors seem to have included delayed union not requiring reoperation in their nonunion calculation, which elevates the nonunion rate compared with this study. In addition, Lodde et al include 6 studies in their review compared with 12 in the current manuscript. Finally, the prior review includes 1 study that performed anterior and lateral plating of the distal femur which was not included in the current review and accounted for 3 nonunions in the previous study.

The nonunion and reoperation rates demonstrated in this study compare favorably with previously published literature on treatment of native distal femur fractures with lateral locked plating alone. Henderson et al[1] performed a review of nonunion and reoperation rates in distal femoral fractures treated with lateral locked plating and found native nonunion rates from 0% to 19% with unplanned reoperation rates from 5% to 20%. In addition, several more recent studies have demonstrated high rates of nonunion in mixed native and periprosthetic cohorts. Moloney et al[33] performed a retrospective review of distal femoral fractures treated with LLP and found a nonunion rate of 24% in a cohort including mostly native distal femur fractures. Rodriguez et al[34] found a nonunion rate of 13.5% in a similar cohort. Harvin et al found a nonunion rate of 35% associated with bridge plating of distal femoral fractures using LLP in a cohort of primarily native distal femoral fractures. Furthermore, 22 of 34 nonunions in this study failed to heal with a secondary operation for bone healing.[35] When combined, published rates of nonunion for LLP alone are markedly higher than the aggregate nonunion and reoperation rates demonstrated in the current systematic review.

Unfortunately, the literature directly evaluating the efficacy of medial and lateral dual plating relative to other modalities of distal femoral fracture fixation is scarce. We identified 4 studies that directly compared treatment of distal femur fractures with medial and lateral dual plating versus lateral locked plating alone.[7,31,32,36] Zhang et al performed a prospective randomized trial of lateral versus medial and lateral DP in 32 patients with OTA/AO 33.A2/A3 distal femoral fractures. They demonstrated no differences between groups in complication rate, union rate, or patient reported outcome scores at 12-month follow-up.[7] Bai et al performed a single-center retrospective clinical review for operatively treated distal femoral fractures, 48 of which were treated with LLP and 12 of which that underwent DP. At average follow-up greater than 1 year, they found no difference in union rates, time to union, complications, or patient-reported outcomes between groups, although 1 patient in the single plate group underwent reoperation for nonunion versus no patients in the dual plating group. However, the groups in this series differed in several major respects. All patients in the DP group were classified as having complete articular fractures (OTA/AO 33.C) while only 54% of the LLP group had complete articular injuries. In addition, most of the dual-plated fractures in this series were open (92%) and required bone grafting (92%).[31] By contrast, Bologna et al[6] performed a small retrospective review comparing lateral locked plating alone with medial and lateral dual plating for OTA/AO 33-C2 and 33-C3 fractures, demonstrating a statistically significant difference in union rates favoring dual plating. Liu et al performed a similar single institution retrospective study in OTA/AO 33-A3, 33-C2, and 33-C3 fractures and showed statistically significant differences in incidence of nonunion and reoperation favoring dual plating. In addition, this study suggested that dual plating was predictive of early healing in a multivariate regression analysis.[32]

Overall, existing clinical research on medial and lateral dual plating of native distal femur fractures is limited by primarily retrospective study designs and small cohort sizes. The current data taken together with the encouraging results from several direct comparisons of dual plating with lateral plating alone suggest that dual plating may provide a benefit regarding union rates in native, intra-articular distal femoral fractures. These results are especially encouraging given the biomechanical advantage demonstrated by dual plating in several recent biomechanics studies.[4,7–12] In addition, the studies in the current review used the stringent inclusion/exclusion criteria limited to primarily complex intra-articular or highly comminuted extra-articular fractures, which may suggest that dual plating could provide a reliable fixation strategy in injuries at risk for failure when treated with other fixation constructs. However, higher-quality, prospective research is required to confirm these hypotheses.

### 4.1. Limitations

This study has several limitations. Most importantly, Coleman scoring of the research included in the review suggests that the included studies were of moderate-to-poor quality. While the aggregate nonunion and reoperation rates provided by the current data may be helpful for driving future research, the marginal study quality of existing research on the topic suggests that conclusions regarding the efficacy of dual plating for native distal femoral fractures should be tempered until more high-quality research is available. In addition, only two-thirds of included studies reported complication data, which suggests that complications associated with dual plating of distal femoral fractures are likely under-reported in the current review. Finally, comparisons of dual plating with other fixation constructs are limited. The existing literature comparing DP with LLP is based on small numbers and includes several studies that incompletely

account for selection bias favoring DP for more severe injuries. Direct comparisons of dual plating with other types of distal femoral fixation constructs, such as intramedullary nails or plate–nail combinations, were not found. Future research should investigate clinical outcomes in these areas.

## 5. Conclusions

Clinical research interest in DP of distal femoral fractures has markedly increased in the past few decades. The current data suggest that DP of native distal femoral fractures is associated with favorable nonunion and reoperation rates compared with previously published rates associated with LLP alone, which range from 0% to 19% in prior literature.[1] In the current review, DP of distal femoral fractures was associated with acceptable rates of complications and generally good functional outcomes. More high-quality, directly comparable research is necessary to validate the conclusions of this review.

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