

Dual Plating for Periprosthetic Distal Femoral Fractures Following Total Knee Arthroplasty: A Systematic Review

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Francesco Roberto Evola^{1,2}, Marco Vacante³, Claudia Cucuzza⁴, Giuseppe Evola^{2,5}

¹Department of Orthopaedic and Trauma Surgery, “Cannizzaro” Hospital, 95100 Catania, Italy

²Department of Biomedical and Biotechnological Sciences, University of Catania, 95100 Catania, Italy

³Unit of Internal Medicine Critical Area, “Garibaldi” Hospital, 95100 Catania, Italy

⁴Department of Emergency, University of Catanzaro, 88100 Catanzaro, Italy

⁵Surgery Department, “Garibaldi” Hospital, 95100 Catania, Italy

AIM: The demand for total knee arthroplasty (TKA) is projected to double over the next decade; consequently, the incidence of periprosthetic fractures associated with TKA is also rising. One of the most frequently used constructs is a single lateral locking plate, chosen for its ease of application and familiarity. However, single lateral plating has been associated with a high incidence of nonunion, complications, and revision. Augmenting the lateral plate construct with a medial plate decreases the likelihood of failure, offering stronger fixation for low periprosthetic fractures. The aim of this study was to review the existing literature on dual plating for distal femoral fractures in patients undergoing TKA.

METHODS: A systematic review of scientific articles listed in medical databases (PubMed, Scopus) from September 2014 to December 2024 was carried out, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Data collected included author name, study design, patient demographic characteristics, clinical results, radiological outcomes, postoperative complications or adverse events, length of follow-up, cause and rate of failure, and time to full weight-bearing.

RESULTS: Of the 895 articles identified, 690 did not meet the eligibility criteria and were excluded. Thirty-eight articles underwent full-text review, and six studies were included in the final analysis. Five were retrospective studies and one was a case series. The total number of patients was 137 (16 male, 121 female), with study sizes ranging from 15 to 38 patients. The double plate technique was most frequently applied in Su type 3 fractures. Dual plating resulted in positive clinical outcomes and a satisfactory union rate in comminuted distal femoral fractures: bone callus formation was observed in 135 of 137 patients (98.5%). Immediate postoperative weight-bearing was permitted in three of the six studies, while in two others it was delayed until 10–12 or 23 weeks. Osteosynthesis failure occurred in only two cases (2%). Secondary intervention was required in nine cases (6.5%), and complications were reported in 24 patients (17.6%), primarily due to infection or intolerance of plate screws.

CONCLUSIONS: Dual plating is a reliable approach for managing periprosthetic fractures associated with TKA, even in low fractures and when medial or metaphyseal comminution is present, offering high rates of anatomic reduction and low rates of reoperation and complications.

Keywords: periprosthetic fracture; total knee arthroplasty; double plate; locking plate; medial femoral plating; osteosynthesis

Introduction

The demand for total knee arthroplasty (TKA) is projected to double over the next decade, driven by increased life expectancy [1]. Consequently, the incidence of periprosthetic fractures associated with TKA is also rising, with rates ranging from 0.3% to 2.5% following primary surgery and from 1.6% to 3.8% after revision surgery [1,2]. The devel-

opment in clinical practice of sports medicine and new surgical techniques, such as unicompartmental prostheses, will inevitably lead to a further increase in this incidence within the population [3,4]. Risk factors for periprosthetic fractures include osteoporosis, female sex, older age, rheumatoid arthritis, steroid use, and anterior femoral notching [5]. Treatment approaches depend on the case and may involve conservative management, plate fixation, retrograde intramedullary nailing, external fixation, or revision arthroplasty [6,7]. Non-surgical treatment is rarely recommended and is typically associated with poor outcomes. Revision arthroplasty allows for immediate weight-bearing postoperatively and reduces the risk of fracture nonunion. However, while arthroplasty eliminates nonunion as a potential failure mode, it remains a high-risk procedure, with infection rates ranging from 3% to 14%. Moreover, risks of peripros-

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Correspondence to: Francesco Roberto Evola, Department of Orthopaedic and Trauma Surgery, “Cannizzaro” Hospital, 95100 Catania, Italy; Department of Biomedical and Biotechnological Sciences, University of Catania, 95100 Catania, Italy (e-mail: robertoevola@virgilio.it).

thetic refracture, chronic pain, and long-term complications such as aseptic loosening have been reported [8,9]. As a result, revision arthroplasty should be carefully considered in patients with a long life expectancy [10,11]. The main disadvantages of fixation include the potential for nonunion and construct failure [12]. Choosing the most appropriate surgical method for distal femoral fractures remains challenging because of factors such as bone quality, severity of osteoporosis, limited bone stock for fixation, medial cortical comminution, fracture extent, and changes in blood supply [13–16].

Several factors complicate the orthopaedic management of these injuries, including the need for sufficient fixation that allows early weight-bearing without risking loss of reduction or malalignment. The goal of surgical fixation for these fractures is to achieve anatomical reduction, preserve the blood supply, and ensure stable internal fixation to enable early mobilisation [17]. Poor clinical outcomes resulting from fixation failure and malunion have been documented in the literature [1]. To date, in the absence of a definitive gold standard, the treatment of choice has been internal fixation using either a retrograde intramedullary nail or a locking plate [18]. Nail fixation and reduction can be challenging because of the mismatch between the metaphysis and diaphysis, as well as the prosthesis necessitating a more posterior starting point. While locked plating is advantageous for achieving reduction, it can create a suboptimal mechanical environment for fracture healing. One of the most frequently used constructs is a single lateral locking plate, chosen for its ease of application and familiarity [14,19]. A plate can be applied through a small lateral incision, minimising damage to the surrounding soft tissues. Periprosthetic fractures that extend beyond the anterior flange or involve extensive metaphyseal comminution are likely to result in poor outcomes with single lateral plating because of limited bone stock. This may lead to insufficient fixation strength and loss of the medial buttress, resulting in varus collapse, fixation failure, and nonunion [13,20]. Conventional single lateral locked plating for periprosthetic distal femoral fractures (PDFFs) has been associated with a nonunion rate of up to 22% [14,17,21], with complications such as loosening, hardware failure, or malalignment ranging from 5% to 7% and a revision rate between 19% and 23% [1,22]. Construct failure following unilateral plating has been linked to factors such as medial or metaphyseal comminution, low fractures, osteoporotic bone, and severe bone loss [12,23]. It is important to note that most, if not all, of these patients in previous studies were non-weight-bearing postoperatively, which presents clinical challenges, particularly in elderly and frail individuals.

Augmenting the lateral locked plate construct with a medial plate decreases the likelihood of failure [17,24]. Dual plating stabilises both columns of the distal femur, offering stronger fixation for low periprosthetic fractures. It was introduced to address the limitations of internal fixation in

unstable or comminuted distal femoral fractures, resulting in better clinical outcomes, higher union rates, and lower revision rates than with conventional single lateral plating [13,23,25,26]. Initial biomechanical studies have demonstrated that these constructs provide greater axial and torsional stiffness than do single-implant constructs [25,27]. Moreover, double plating with an anteromedial plate improves stabilisation in the coronal plane while offering additional support in the sagittal plane. As a result, this technique may help reduce the risk of TKA component failure or wear following PDFFs [5]. Dual plating is typically indicated in patients with limited distal bone stock, metaphyseal comminution, and poor bone quality, particularly in elderly patients. Adding medial plating provides extra stability against varus collapse but may also lead to biological disruption and muscle damage, which could affect bone healing and postoperative range of motion (ROM) [5]. Bologna *et al.* [26] compared knee ROM between single lateral and double plate treatments, finding significantly higher ROM in the single plate group.

The aim of the present study was to review the existing literature on dual plating for distal femoral fractures in patients with TKA, focusing on functional outcomes and the incidence of complications or failure. We hypothesised that this technique will result in a satisfactory bone union rate and a low incidence of failure in PDFFs among patients undergoing TKA.

Materials and Methods

Search Strategy

A systematic review of scientific articles listed in medical databases (PubMed, Scopus) was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Fig. 1) from September 2014 to December 2024 (**Supplementary Material**). Search terms were utilised and adapted for each database to obtain the most accurate results [28]. The search for relevant articles was performed using the following keywords: ['Periprosthetic TKA fracture' OR 'Supracondylar femur fracture' OR 'Periprosthetic distal femur fractures' OR 'Total knee arthroplasty' OR 'Distal femur fracture'] AND ['Double plate' OR 'Locking plate' OR 'Double plating' OR 'Dual plating' OR 'Dual locking compression plate' OR 'Medial femoral plating' OR 'Osteosynthesis' OR 'Fixation' OR 'ORIF']. Articles were identified by combining the two concepts with the operator 'AND'. A manual search, using the references of included manuscripts, was carried out to identify additional articles. The abstracts of the retrieved articles were reviewed to determine their potential inclusion in the study. If the abstract did not provide sufficient detail, the full text was obtained for further evaluation. Two authors (FRE and GE) screened the titles and abstracts according to the inclusion and exclusion criteria. Any disagreement was resolved through inter-

vention by a third author (MV). The search was restricted to English-language literature and human studies.

Inclusion and Exclusion Criteria

The inclusion criteria were clinical studies on PDFFs in patients with knee prostheses treated using a double plate technique, published within the last 10 years. The review included randomised controlled trials, case-control studies, and cohort studies. Studies were required to report a minimum follow-up period of 12 months. Original scientific articles were included if they reported clinical or radiographic outcomes of the treatment of PDFFs and at least one of the following outcome variables: reoperations, complications and adverse events, or causes of procedure failure. If the articles contained data on other surgical methods, only the data related to the use of the double plate were extracted. Original articles were excluded if only the abstract was available, if they contained duplicate data, or if they involved patients with a history of PDFFs, severe neurological diseases, or pathological fractures. Also excluded were biomechanical or anatomical studies, studies focused solely on surgical technique, cadaveric research, reviews, letters, comments, case reports, study protocols, or other study designs. Studies involving concurrent surgical procedures were excluded because these could influence postoperative clinical and radiographic scores. All full texts were independently reviewed by the authors for the final decision.

Risk of Bias

Full-text articles were analysed to identify clinical studies that met the inclusion criteria. Each article was assigned a level of evidence according to the Oxford Centre for Evidence-Based Medicine guidelines [29] and assessed for risk of bias in randomised trials using the Cochrane Collaboration's tool [30]. Case-control and cohort study was evaluated following the Newcastle-Ottawa Scale guidelines [31]. The assessment of potential bias was carried out by two authors (FRE and GE); in the event of any disagreement, both authors discussed the issue to reach a final decision.

Data Extraction

An electronic form was developed for data extraction, and the authors independently extracted data from the included studies. Potential duplicate data were verified by comparing authors' names and recruitment locations; to avoid patient overlap, only the study with the longest follow-up was considered. Any disagreement was resolved through discussion and consensus among the authors. The information retrieved from the reports included the first author's name, study design, patient demographic characteristics (number of patients, mean age, sex, Su classification, diagnosis of osteoporosis, and presence of bone comminution), clinical results (knee ROM, Western Ontario and Mc-

Master Universities Osteoarthritis Index (WOMAC), and Knee Society Score (KSS)), radiological outcomes (union, nonunion, time to union, mechanical lateral distal femoral angle (mLDFA), anatomic varus-valgus angle of the knee, and varus collapse), postoperative complications or adverse events, length of follow-up, cause and rate of failure, and time to full weight-bearing.

Su *et al.* [32] proposed a classification system for periprosthetic supracondylar fractures of the distal femur based on the extent and location of the fracture line, which aids in preoperative planning.

In the literature, malunion is defined as a coronal deformity (varus or valgus angulation) of $>5^\circ$, a sagittal deformity (anterior or posterior angulation) of $>10^\circ$, a rotational deformity of $>15^\circ$, and/or shortening of >2 cm [3]; we defined the varus collapse angle as the increase in the mLDFA from the immediate postoperative period to the follow-up period. Mechanical failure due to varus collapse was considered a change in alignment of $>5^\circ$ in the coronal plane on the immediate postoperative radiograph [33].

The primary outcome was assessment of the clinical and radiographic results. The secondary outcomes were analysis of the failure rates, secondary interventions, and complications across the different studies.

Statistical Analysis

The data were statistically analysed using the Statistical Package for the Social Sciences for Windows (Version 16, SPSS Inc., Chicago, IL, USA). The analysis was strongly influenced by the type and availability of the data. Parametric data are presented as mean and standard deviation, while non-parametric data are expressed as median and interquartile range. Continuous data were analysed using analysis of variance for parametric variables and the Kruskal-Wallis test for non-parametric variables; categorical variables were analysed using the chi-square test. A p -value of <0.05 was considered statistically significant.

Results

Search Results

Of the 895 articles identified through the literature search, 690 did not meet the eligibility criteria and were excluded. Thirty-eight articles underwent full-text review, and only six studies [5,12,23,33–35] were included in the systematic review.

Study and Patient Characteristics

The characteristics of the studies included in our analysis are summarised in Table 1 (Ref. [5,12,23,33–35]). Five studies [5,12,33–35] were retrospective (Level III), and one [23] was a case series (Level IV). The number of patients included in the studies ranged from 15 to 38, with a total of 137 participants—16 male and 121 female. All studies reported a higher proportion of female than male patients.

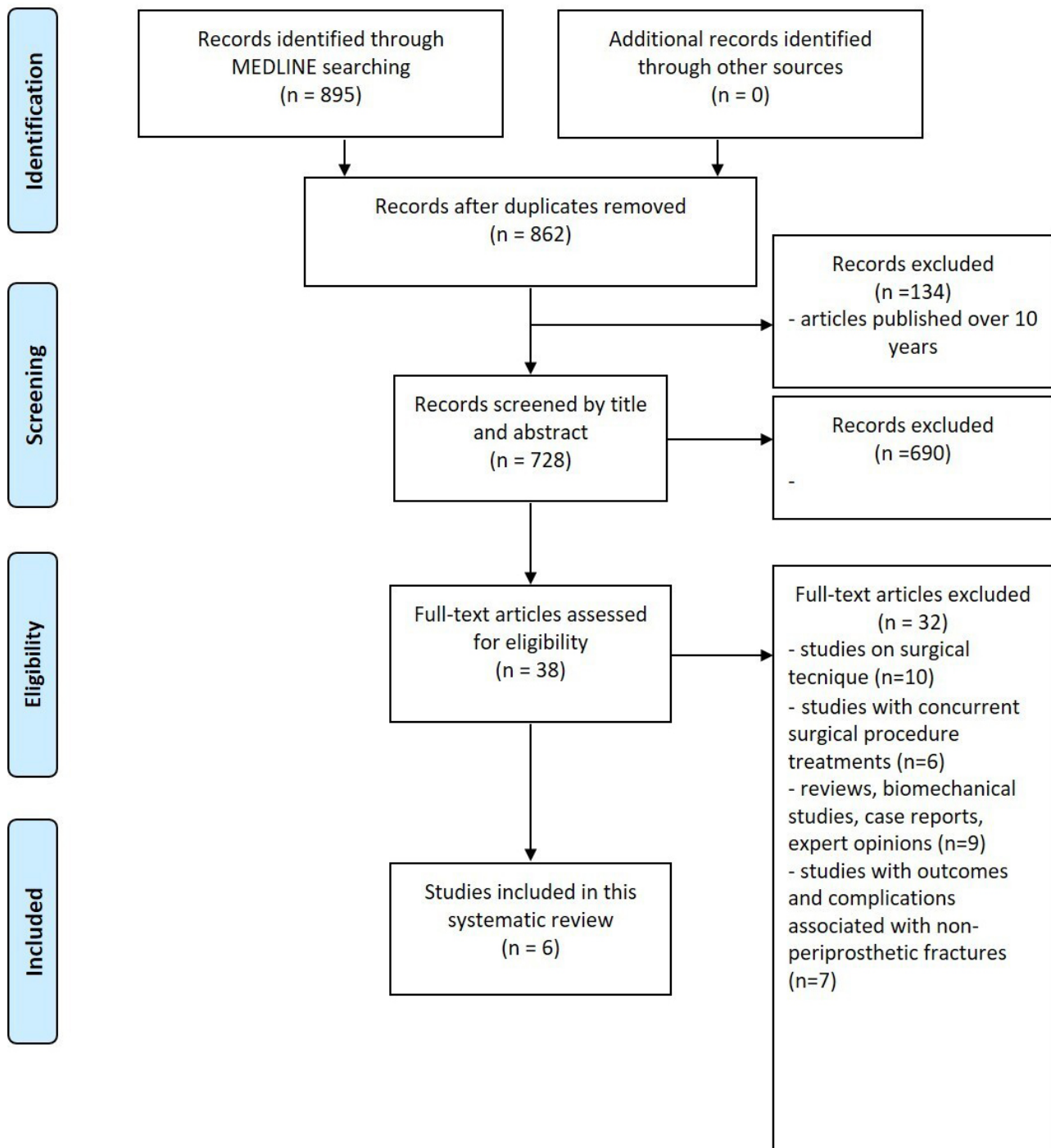


Fig. 1. Flow chart illustrating the inclusion of studies in the review from September 2014 to December 2024.

The average age of the patients did not show a statistically significant difference between the studies ($p = 0.45$, $F = 1.16$). Osteoporosis was reported in five of the six studies, with no significant difference in its incidence across these five studies ($p = 0.42$, $\chi^2 = 3.83$).

According to the Su classification [32], there were 7 cases of type 1 fractures, 42 of type 2, and 88 of type 3 treated with the double plate procedure. The double plate technique was used more frequently in patients with Su type 3 fractures (64%). The most commonly used combinations

were lateral minimally invasive plate osteosynthesis with a distal femoral locking plate, and medial minimally invasive plate osteosynthesis via the subvastus approach using either a proximal humeral locking system or a contoured proximal tibial plate.

Clinical Evaluation

The clinical outcomes of the studies are summarised in Table 2 (Ref. [5,12,23,33–35]). Knee ROM was reported in four of the six studies, the KSS in two studies, and walking

Table 1. Overview of study types, patient demographics, and fracture characteristics.

First author	Type of study	Total patients	Sex	Age, years (range)	Follow-up period, months (range)	Osteoporosis	Su classification	Comminution
Seo [33]	Retrospective	29	1 M/28 F	73.0 ± 7.8 (52–85)	39.7 ± 37.2 (12–138)	13 of 29 (45%)	Type 1: 2 (7%) Type 2: 4 (14%) Type 3: 23 (79%)	Total: 48% Type 1: 0% Type 2: 50% Type 3: 52%
Park YG [5]	Retrospective	18	0 M/18 F	74.8 ± 5.9 (68–89)	14.8 ± 10.2 (12–43)	5 of 18 (28%)	Type 1: 2 (11.1%) Type 2: 3 (16.7%) Type 3: 13 (72.2%)	NA
Andring [34]	Retrospective	38	7 M/31 F	75.9 ± 11.3	19.8 ± 16.1	15 of 38 (40%)	Type 1: 0 (0.0%) Type 2: 23 (57.9%) Type 3: 15 (42.1%)	NA
Medda [23]	Case series	16	2 M/14 F	78.6 ± 13.1	14.3 ± 5.1 (6–24)	3 of 16 (19%)	Type 1: 0 (0.0%) Type 2: 7 (43.8%) Type 3: 9 (56.2%)	NA
Kriechling [12]	Retrospective	15	2 M/13 F	78 (73–88)	2.4 years (2.0–4.2)	5 of 15 (33%)	Type 1: 3 (20%) Type 2: 5 (33%) Type 3: 7 (47%)	7 of 15 (47%)
Park KH [35]	Retrospective	21	4 M/17 F	76 (56–90)	Final follow-up: 24	NA	Type 1: 0 (0%) Type 2: 0 (0%) Type 3: 21 (100%)	NA

M, male; F, female; NA, not available.

Table 2. Clinical outcomes of the studies.

First author	Clinical parameters	Time to full weight-bearing, weeks (range)
Seo [33]	Average final knee ROM: 130° Walking ability (Koval score): 1.7 KSS: 73.8 ± 18.1	23.4 ± 10.7 (5.52)
Park YG [5]	Mean final knee ROM: 110.3° ± 15.7° (80°–135°) Modified WOMAC score: 37.6 ± 8.5 (24–53)	NA
Andring [34]	Mean final knee ROM: 111.0° ± 13.2°	Full weight-bearing postoperatively: 86.8%
Medda [23]	NA	Full weight-bearing postoperatively: 69.2%
Kriechling [12]	NA	Full weight-bearing postoperatively
Park KH [35]	Average final knee ROM: 114° (70°–130°) KSS: 94 (83–100)	Full weight-bearing allowed at 10–12 weeks postoperatively

ROM, range of motion; KKS, Knee Society Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

ability using the Koval score and modified WOMAC score in only one study each. Park YG [5], Andring [34], and Park KH [35] reported an average final knee ROM of 110.3°, 111.0°, and 114.0°, respectively, while Seo [33] observed a higher average final ROM of 130.0°, although no statistically significant difference was found ($p = 0.2$, $F = 0.03$). Seo [33] reported a KSS of 73.8, whereas Park KH [35] reported a KSS of 94.

Full postoperative weight-bearing was permitted immediately in three of the six studies, covering >70% of the sample, while in two other studies it was delayed until 10–12 or 23 weeks after the intervention.

Radiological Assessment

The radiographic outcomes of the studies are summarised in Table 3 (Ref. [5,12,23,33–35]). All studies evaluated the formation of bone callus, four through X-ray and two through computed tomography (CT). Bone union was defined as the formation of a callus bridging the fracture site on both anteroposterior and lateral radiographs, or on sagittal and coronal reconstructed CT images involving two or more cortices [33]. CT scans offer advantages in detecting callus bridging. Evaluating bone bridging in fractures fixed with dual plates using two orthogonal radiographs is generally challenging because the presence of two plates and multiple screws obscures the cortical surface and complicates the assessment. Some authors have used a Radiographic Union Score for Hip (RUSH) of ≥ 15 as a supplementary measure [36]. Nonunion was defined as the absence of bone healing signs 6–9 months after surgery.

Bone callus formation was observed in 135 of 137 patients, while bone healing did not occur in one patient each from the studies by Seo [33] and Park KH [35]. There were no statistically significant differences in the frequency of bone union across the studies ($p = 0.7$, $\chi^2 = 3.67$).

The time required for bone callus formation was reported in three of the six studies. In those using X-ray, callus formation occurred within 14 to 18 weeks, while in studies using CT, it took approximately 34 weeks.

The mLDFA was calculated only in the studies by Seo [33] and Park KH [35], with final values of 90.5° and 89.6°,

respectively. In both studies, no varus collapse was observed between the postoperative control and follow-up. The anatomical varus-valgus angle of the knee was assessed in the studies by Park YG [5] and Andring [34], with values of 3.2° and 2.0°, respectively.

Failure, Secondary Intervention, and Complications

Failure, secondary intervention, and complications related to the procedure are summarised in Table 4 (Ref. [5,12,23,33–35]). Osteosynthesis failure was observed in only two cases in which bone consolidation did not occur, leading to plate fracture or detachment. Secondary intervention was required in nine cases. Reasons for reoperation or return to the operating theatre included fixation failure in two cases, loosening or failure of the distal locking screw in three, and symptomatic or irritating hardware in four. Complications were observed in 24 patients, mainly due to infections or intolerance of the plate screws. No statistically significant differences were found in failure rates ($p = 0.59$, $\chi^2 = 3.68$) or secondary interventions ($p = 0.55$, $\chi^2 = 3.95$) across the selected studies.

Risk of Bias

Table 5 (Ref. [5,12,23,33–35]) shows the risk of bias for each study. We included five retrospective studies and one case series. The score for each item of the Newcastle-Ottawa Scale guidelines for comparative studies is reported in the table. The total points ranged from 7 to 9. The overall quality of the studies was good.

Discussion

PDFFs around TKAs are frequent fragility fractures in elderly or frail patients, and their incidence is increasing worldwide [37]. Nonetheless, there is ongoing debate regarding the optimal surgical treatment. Despite several systematic reviews on this topic, conducting randomised controlled trials remains challenging because of the heterogeneity and complexity of both the injuries and the patient population [38,39].

Table 3. Radiographic outcomes of the studies.

First author	Union	Nonunion	Time to union, weeks (range)	mLDFA	Varus collapse angle
Seo [33]	28 CT studies	1	33.8 ± 14.3 (12–60)	Immediately postoperatively: 90.5° ± 2.9° Final: 90.5° ± 3.5°	None (−0.1° ± 2.0°)
Park YG [5]	18 radiologic studies	0	18.4 ± 9.8 (10–51)	NA	NA
Andring [34]	38 radiologic studies	0	NA	NA	NA
Medda [23]	16 radiologic studies	0	NA	NA	NA
Kriechling [12]	15 CT studies	0	NA	NA	NA
Park KH [35]	20 radiologic studies	1	14 (10–21)	Final: 89.6° (85°–92°)	None

mLDFA, mechanical lateral distal femoral angle; CT, computed tomography.

Table 4. Failure, secondary intervention, and complications in the studies.

First author	Failure	Secondary intervention	Reason for reoperation	Complications
Seo [33]	1	4	Mechanical failure: 1 Junctional fracture: 1 Symptomatic hardware: 2	None
Park YG [5]	0	0	None	Malunion: 3 (16.7%) Shortening: 1 (5.6%)
Andring [34]	0	2	Loosening distal locking screw: 1 Hardware failure: 1	Infection: 2 (5.2%) Hardware failure: 7 (18.4%)
Medda [23]	0	1	Removal of prominent screw: 1	Screw fracture: 5 (38.5%)
Kriechling [12]	0	1	Irritating metalwork: 1	Irritating metalwork: 1 (7%) Chronic wound problems: 1 (7%)
Park KH [35]	1	1	Screw breakage and loosening: 1	Superficial infection: 3 (14.2%) Wound dehiscence: 1 (5%)

The orthopaedic surgeon must strike a balance between short-segment fixation and the need for strong fixation around a prosthesis, particularly in osteoporotic bone, where the inability to bear weight can have significant clinical consequences.

For fractures that are not suitable for intramedullary nailing—such as low fractures, interprosthetic fractures, or those involving a stemmed or solid boxed femoral component—lateral locking plates are commonly employed. A comparison between locking plating and retrograde intramedullary nailing revealed no statistically significant differences in nonunion rates, although retrograde nailing demonstrated a quicker return to full weight-bearing than did lateral plating [34].

A systematic review revealed that locking plating resulted in significantly fewer cases of malunion than did retrograde intramedullary nailing [40]. The authors proposed three reasons for the superior performance of locking plates in reducing malunion rates. First, the starting point for retrograde nailing is influenced by the position of the femoral component, which can lead to malreduction. Second, retrograde nailing does not adequately fill the wide metaphyseal intramedullary space, increasing the risk of distal fragment movement relative to the nail. Third, locking plates offer more fixation options for the distal fragment than retrograde nailing. Additionally, malunion in these fractures can lead

to improper component positioning, which may contribute to component failure or wear [5].

Fixation failure due to cantilever bending is a concern when using isolated unilateral lateral locking plates for low fractures, particularly in patients with poor bone quality or medial and metaphyseal comminution [41]. Comminuted fractures are typically treated with longer bridging constructs, where the plate length is at least twice the length of the comminuted area, and four well-spaced bicortical screws are placed into the shaft [33]. Various radiological, cadaveric, biomechanical, and clinical studies have demonstrated promising results with the safe and effective use of additional medial plates for distal femoral fractures. Dual plating constructs help convert cantilever forces into on-axis forces, offering more stable fixation [12,26,33,42]. The benefits of dual plating over single plating include more anatomical reduction, a stronger biomechanical construct, and a theoretical decrease in construct failure [12]. In a more recent biomechanical study by Prayson *et al.* [43], the dual plate construct demonstrated a significant increase in resistance to torsional and axial stress in osteotomised femurs.

Since Sanders *et al.* [44] introduced the dual plating concept in 1981, initially for fractures of native femora, cohort study have highlighted its effectiveness [45]. Although the literature on dual plating for PDFFs is limited to small case

Table 5. Risk of bias according to Newcastle-Ottawa Scale guidelines for comparative studies.

First author	Study design	Selection points	Comparability point	Outcome/exposure points	Total points	Quality of study
Seo [33]	Retrospective	4	2	3	9	Good
Park YG [5]	Retrospective	4	2	2	8	Good
Andring [34]	Retrospective	4	2	3	9	Good
Medda [23]	Case series	4	1	2	7	Good
Kriechling [12]	Retrospective	4	2	3	9	Good
Park KH [35]	Retrospective	4	2	2	8	Good

series, study have reported union rates ranging from 87% to 100% [12]. Dual plate fixation was employed in fractures with a low location but sufficient distal bone to accommodate locking screws, as well as in cases with metaphyseal comminution. This approach resulted in high union rates and low complication rates [12].

The primary benefits of the dual plate approach include the ability to utilise the reductive power of both the medial and lateral cortices, enhanced control and stability of medial comminution, improved coronal plane alignment, and increased fixation in osteoporotic bone. It also prevents the common ‘golf club’ deformity, allows for early weight-bearing, reduces pain, and facilitates a quicker return to baseline ambulation. Additionally, this technique avoids the deformity caused by intramedullary nailing with its posterior starting point due to the prosthesis, aids in restoring limb alignment, and can be used with any primary TKA prosthesis. While distal femoral fractures with metaphyseal comminution may benefit from dual plating in preventing varus collapse, the risk remains elevated because of loss of the medial buttress effect.

Some surgeons are concerned that dual plating may increase the risk of nonunion due to reduced fracture mobility or osteonecrosis because soft tissue stripping to access both sides of the femur may create a ‘dead bone sandwich’ [12–14]. In a recent cadaveric study, Rollick *et al.* [46] showed that double plating did not significantly affect the blood supply to the distal femur: single lateral locking plating reduced the distal femoral blood flow by 21%, while dual plating reduced it by 24%. This suggests that most of the vascular disruption associated with open reduction and internal fixation of the distal femur results from lateral locked plating, rather than from the addition of a medial plate. Medial plating is not commonly performed because of the risk of femoral artery injury. However, a recent study showed that a medial plate can be safely positioned on the anteromedial aspect of the distal femur, extending up to 8 cm distal to the lesser trochanter [8]. Another cadaveric study indicated that the distal 60% of the femur, up to approximately 16 cm proximal to the adductor tubercle, is a safe zone for medial plating [47,48].

Therefore, medial plating combined with minimally invasive plate osteosynthesis and a lateral locking compression plate is not only safe but also provides sufficient rigidity to support a medial-sided fracture. A common concern among

surgeons, however, is the lack of familiarity with the medial approach to the distal femur [17].

This systematic review demonstrated that dual plating results in positive clinical outcomes and achieves satisfactory union in comminuted distal femoral fractures in patients with TKA. However, the conclusions of this review are limited by the inclusion of various fracture types (albeit with appropriate indications), different medial implants, and varying methods of outcome assessment.

The most frequently used fixation technique involved placing plates on both the medial and lateral surfaces of the distal femur. In the literature, authors who positioned plates on the lateral and anterior (anteromedial) surfaces of the distal femur reported fibrosis in up to 14% of patients, attributed to significant damage to the suprapatellar tissues, leading to joint stiffness [17].

This review highlights clinical outcomes following the use of double plating, which are consistent with those reported in the literature. Knee range of motion was documented in four of the six studies, with reported values of 110.3°, 111.0°, 114.0°, and 130.0°. The KSS was included in two studies, with reported scores of 73.8 and 94. Additionally, walking ability was assessed using the Koval score [1.7] and the modified WOMAC score (37.6 ± 8.5), both of which were reported in a single study.

The primary benefit of this technique is the ability to bear weight early after surgery, even in elderly or frail patients. Patients who underwent dual plating were able to bear weight immediately postoperatively, unlike those treated with lateral locking plate fixation. In three of the six studies, full weight-bearing was permitted immediately after the procedure, accounting for more than 70% of the patients. By contrast, two other studies delayed full weight-bearing for 10–12 weeks or up to 23 weeks. The enhanced mechanical stability may reduce pain during early weight-bearing and could potentially accelerate the return to baseline ambulation levels.

According to the literature, the nonunion rate following dual plating for native distal femoral fractures ranges from 0.0% to 12.5%, with delayed union occurring in up to 33.3% of cases [17]. In this review, bone callus formation was observed in 135 of 137 patients, equating to a rate of 98.5%. The time to bone callus formation in studies using X-rays ranged from 14 to 18 weeks, while in studies utilising CT, it took approximately 34 weeks. Several factors

could explain this difference. First, studies using CT may have applied stricter criteria for bone union. Second, the dual plate construct may have been too rigid, restricting micromotions between fracture fragments. Because locking plate osteosynthesis relies on indirect bone healing, minimal micromotion in a rigid construct with a short working length could delay the healing process [33]. This same rigidity and short working length may also account for the low incidence of mechanical failures. Third, medial plates could contribute to vascular insufficiency, potentially delaying healing [33].

The mLDFA was calculated in the studies by Seo [33] and Park KH [35], with final results of 90.5° and 89.6°, respectively. In both studies, no varus collapse was observed between the postoperative control and follow-up. To achieve neutral mechanical alignment, the ideal target for the mLDFA was set at 90° for periprosthetic fractures [33]. Osteosynthesis failure was observed in only two cases (2%) in which bone consolidation did not occur. Secondary intervention was required in nine cases (6.5%), and complications were reported in 24 patients (17.6%), mostly due to infections or intolerance to the plate screws.

Although this systematic review provides valuable insights, there are several limitations. First, the selection criteria were quite strict. Additionally, a meta-analysis was not conducted, and the population, interventions, comparisons, outcomes (PICO) framework was not fully applied in the search because of the absence of a control group. Second, most of the studies were retrospective and had small sample sizes because PDFFs are relatively rare. The predominance of retrospective studies and case series, which are associated with lower levels of evidence, introduced potential issues such as selection bias and information bias that may have affected the reliability of the conclusions. Furthermore, there was considerable heterogeneity among the included studies in terms of fracture type, surgical technique, implant type, and follow-up duration, which may have impacted the consistency and generalisability of the findings. Third, the follow-up duration varied across the studies, ranging from 14.3 to 39.7 months, limiting the ability to assess long-term clinical outcomes and complications. Finally, the use of different clinical functional scores may have resulted in incomplete or inaccurate comparisons of outcomes.

Conclusions

Dual plating is a reliable approach for managing PDFFs, even in low fractures and in the presence of medial or metaphyseal comminution, offering high rates of anatomic reduction and low rates of reoperation and complications. Although not yet supported by robust scientific literature, this technique appears to provide greater stability and improved fracture reduction in patients with osteoporosis and multiple fractures. Achieving a successful outcome on the first attempt is crucial, particularly in frail, elderly patients who

may not be suitable candidates for additional surgeries. A long-term, large-scale, prospective randomised controlled trial is needed to further evaluate the effectiveness of dual plating compared with traditional single-plate fixation.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

FRE and GE contributed to conception and design of the study. FRE and MV reviewed the literature. MV and CC analysed and interpreted the data. FRE, MV and GE contributed to drafting the article and making critical revisions related to important intellectual content of the manuscript. MV, CC and GE contributed to important manuscript editing and review. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at <https://www.annaliitalianidichirurgia.it/journal/AIC/article/path/pii/AIC4004>.

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