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Background: The incidence of distal femur fractures is approximately 37 per 100,000 person-years. Typically, distal femur fractures are caused by a high-energy injury mechanism in young men or a low-energy mechanism in elderly women. Managing these fractures can be a challenging task. Most surgeons agree that distal femur fractures need to be treated operatively to achieve optimal patient outcomes. The articular fracture component is usually treated with open reduction and internal lag screw fixation or external tension wire fixation (Ilizarov). However, there is no consensus on the type of implant for the fixation of the metaphyseal-diaphyseal fracture component.

Objective: The aim of this study is to systematically summarize and compare the results of different fixation techniques (traditional compression plating, antegrade nailing, retrograde nailing, submuscular locked internal fixation, and external fixation) in the operative management of acute nonperiprosthetic distal femur fractures (AO/OTA type 33A and C) and the characteristics of the fractures for each treatment (articular/nonarticular and open/closed). Additionally an attempt was made to evaluate the impact of surgical experience on nonunion rate, fixation failure rate, deep infection rate, and secondary surgical procedure rate. In the context of this article compression plating relates to techniques/implants that require compression of the implant to the femoral shaft—it does not relate to interfragmentary compression.

Key Words: distal femur fracture, supracondylar femur fracture, intercondylar femur fracture, systematic review, meta-analysis, evidence-based

STUDY IDENTIFICATION (SEARCH DATE: MARCH 2005)
1. Cochrane Database: Keywords: “distal femur,” “supracondylar femur,” “intercondylar femur;” 0 hits.
3. Review of bibliographies of identified articles revealed 3 additional articles.
4. OTA online abstracts database of the 2003 annual meeting: Search query: “fracture & [femur|femoral] & 2003” with 50% agreement; 50 hits; 1 relevant but redundant with subsequent publication.
5. AAOS online abstract database of the 2003 and 2004 annual meeting: Search query: “fracture AND (femur OR femoral);” 36 hits; none relevant.

Case reports were not considered. Articles were excluded when they dealt exclusively with, or contained more than 30% of periprosthetic fractures, and/or nonunion revisions, and/or unicodylar fractures (AO/OTA type 33B). One series using Zickel nails and 1 primary total knee arthroplasty series were also not included. From the remaining articles, an attempt was made to extract and exclude periprosthetic fractures and revision cases, which was possible in 1 article. Four articles were not included because they appeared to present preliminary data that were subsequently published in updated reports. Insufficient data were presented in 1 article. Data extraction in a meaningful way was not possible in 5 articles because of a variety of different implants/treatment options or a variety of fracture types including femoral shaft and/or proximal femur fractures.

The total number of cases included after review was 47.

HIGHEST AVAILABLE EVIDENCE
1. One randomized controlled trial (RCT) with methodological limitations comparing operative (dynamic condylar screw, DCS) and nonoperative (traction) treatment. (EBM-level 2)
2. One prospective cohort study comparing internal (locked) fixation with retrograde intramedullary nailing (rIMN). (EBM-level 2)
3. Forty-five case series of compression plating, antegrade nailing, retrograde nailing, and internal (locked) or external fixation. (EBM-level 4)

METHODS: DATA ANALYSIS

From all articles, the following parameters were extracted: the fixation technique/implant, sample size, average age, gender, percentage of fractures with articular involvement, percentage of fractures with severe articular involvement (AO/OTA type C3)$^{22}$, percentage of open fractures, percentage of grade III open fractures$^{23}$, number of operating surgeons, and nonunion rate, fixation failure rate, deep infection rate, and secondary surgical procedure rate as outcome parameters.

The results were stratified by the fixation technique used: traditional plating techniques that require compression of the implant to the femoral shaft (blade plate, DCS, nonlocking condylar buttress plate), antegrade nailing fixation, rIMN, submuscular locked internal fixation (less invasive stabilization system, LISS), and external fixation. The mean values were calculated for all included fractures and for each fixation technique separately. All values were weighted by the sample size of each study. Outcome parameters between the compression plating group and the internal fixation group were compared using Fisher exact test. Averages and 95% confidence intervals (CI) of the corresponding relative risks and relative risk reduction (RRR) were calculated.

A second comparison was made between studies that reported a patient/surgeon ratio of >21 with the remaining studies. Outcome parameters were evaluated using Fisher exact test and relative risks and RRRs were calculated. Averages and 95% CI are reported.

Outcome Parameter

The outcome parameters were defined as follows:

1. Nonunion rate: The nonunion rate includes nonunions and secondary surgical procedures for delayed unions, infections leading to nonunion, and implant exchange before union. Fixation failures leading to an implant exchange before union are therefore included in the nonunion rate. Fixation failure after bony union was not included in the nonunion rate.

2. Fixation failure rate: The fixation failure rate includes events that lead to a secondary surgical procedure. This included screw loosening, implant cutout or migration, implant breakage leading to a nonunion or malunion, and fractures above the implant. Asymptomatic screw/implant breakage or loosening that did not lead to a secondary surgical procedure was not included.

3. Deep infection rate: The deep infection rate includes all infections except superficial ones not requiring surgical debridement and pin infections in the external fixator group.

4. Secondary surgical procedures: The secondary surgical procedure rate includes any reported secondary surgical procedure related to the distal femur fracture. This includes partial (screw only) or complete implant removal and also the patient’s refusal of an indicated reoperation as determined by the surgeon. It does not include planned staged bone grafting in open fractures or planned irrigation and debridements and external fixator removal in the external fixation group. In some articles, it was not clear if some of the described secondary surgical procedures were performed on the same or different patients. In those cases, we assumed that they did occur in the same patients resulting in the lowest possible rate.

RESULTS

Level 2 Evidence (RCT): N = 36

A RCT comparing operative treatment (DCS, n = 17) and non-operative treatment (traction, n = 19) resulted in good or excellent results in 53% of the patients treated operatively compared to 31% treated nonoperatively by the criteria of Schatzker$^{24}$ with no nonunions or deep infections in both groups and 1 fixation failure (6%) in the DCS group.$^{32}$

Level 2 Evidence (Prospective Cohorts): N = 39

A comparative observational study between internal locked fixation with the LISS (n = 20) and rIMN (n = 19) revealed no significant differences with regard to rates of nonunion (both 10%), fixation failure (both 0%), infection (LISS 0% versus rIMN 6%), and secondary surgical procedures (both 10%) at 1 year follow-up.$^{51}$

Level 4 Evidence (Case Series): N = 1614

Forty-five case series were identified with a total of 1614 fractures that were treated operatively by either compression plating,$^{30,32,34,41,45,46,53–55,58,59,63,64,69–71}$ antegrade intramedullary nailing (aIMN),$^{31,35,49,68}$ rIMN,$^{29,33,37–40,43,44,48,50,51,21,60,62,65}$ locked internal fixation,$^{36,47,51,57,61,17,66,67}$ blade plate, or external fixation.$^{27,28,42,50,52}$ In all treatment options, additional internal screw and/or plate fixation was performed first if the articular surface was fractured.

All operatively treated cases were summarized (45 case series, 1 comparative study with 2 arms and the operative arm of 1 RCT; total N = 1670). The average follow-up was 2.5 years. The average age of the patients was 49 years, and 47% were females. The articular surface was fractured in 58% of the cases—in 22% severely (AO/OTA type C3). Twenty-seven percent of all fractures were open, and according to the Gustilo-Anderson classification, 10% of all fractures were grade III open. Overall, the average nonunion rate was 6.0%, the fixation failure rate was 3.3%, the deep infection rate was 2.7%, and the average secondary surgical procedure rate was 16.8%.

The compression-plating group included the following implants: blade plate:41%, DCS: 33%, (nonlocking) condylar buttress plate: 23%, and others 3%. Further subdivision or data abstraction within the plating group was not possible. In all series, locked internal fixation was performed with the LISS.
The injury/fracture spectrum was different for the 4 fixation techniques; therefore, a comparison of outcome parameters is limited. The percentage of articular fractures was highest in the external fixation group (86%) and lowest in the aIMN group (22%) and the percentage of open fractures (External fixation: 59%, aIMN: 17%).

A comparison of outcome parameters between compression plating and locked internal fixation was performed and revealed no statistically significant differences for any outcome parameter. However, there was a statistically nonsignificant RRR of 55% (95% CI: RRR of 80% to RRI of 1%, \( P = 0.056 \)) for deep infection when submuscular locked internal fixation was performed as opposed to traditional compression-plating techniques despite a significantly higher percentage of all open fractures (36% versus 25%, \( P < 0.001 \)) and grade III open fractures (17% versus 7%, \( P < 0.001 \)) in the locked internal fixation group (Fig. 1). On the other hand, there was a nonsignificant RRI in fixation failure of 89% (95% CI: RRI of 365% to RRR of 3%, \( P = 0.062 \)) and a nonsignificant RRI in secondary surgical procedures of 28% (95% CI: RRI of 75% to RRR of 7%, \( P = 0.145 \)) (Fig. 2). No other fixation techniques were compared statistically because of the large differences in fracture characteristics (articular/nonarticular and open/closed). Detailed results are presented in Table 1.

Nine studies were identified that reported the number of involved surgeons; in 3 of them the patient/surgeon ratio was >21.30,47,66 There was a significantly lower rate of secondary surgical procedures in the 3 series with a patient/surgeon ratio of >21 (\( P = 0.046 \)) despite a higher percentage of C3 type articular fractures (\( P = 0.064 \)) and grade III open fractures (\( P = 0.013 \) (Table 2).

| TABLE 1. Fracture Spectrum and Outcome Parameter for Different Fixation Techniques |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Implant/Technique               | Total           | aIMN            | rIMN            | Internal Fixator | Compression Plate |
|                                 | Total no. of series | 48*            | 4              | 15              | 8               | 16              | 5               |
|                                 | Total N          | 1670            | 108            | 472             | 327             | 694             | 69             |
| Average follow-up†              | 30 m (n = 1544)  | 30 m (n = 88)   | 23 m (n = 472) | 16 m (n = 327)  | 16 m (n = 588)  | 31 m (n = 69)  |
| Outcome parameter               | Nonunions       | 6.0% (CI: 4.9–7.2%) | 8.3% | 5.3% | 5.5% | 6.3% | 7.2% |
|                                 | Fixation failure| 3.3% (CI: 2.5–4.2%) | 3.7% | 3.2% | 4.9% | 2.6% | 1.5% |
|                                 | Deep infection  | 2.7% (CI: 2.0–3.5%) | 0.9% | 0.4% | 2.1% | 4.8% | 4.3% |
|                                 | Secondary surgical procedures | 16.8% (CI: 15.3–18.6%) | 23.1% | 24.2% | 16.2% | 12.7% | 30.6% |
| Baseline parameter‡             | Age             | 49 y (n = 1614) | 41 y (n = 88) | 55 y (n = 472) | 54 y (n = 327) | 46 y (n = 658) | 39 y (n = 69) |
|                                 | Articular       | 58.1% (CI: 54.9–59.8%) (n = 1542) | 22.2% (n = 108) | 37.1% (n = 361) | 56.9% (n = 327) | 73.0% (n = 677) | 85.5% (n = 69) |
|                                 | Severe articular (C3) | 21.6% (CI: 19.4–24.0%) (n = 1235) | 2.8% (n = 108) | 12.8% (n = 227) | 29.8% (n = 289) | 19.6% (n = 542) | 63.7% (n = 69) |
|                                 | Open (Total)    | 26.9% (CI: 24.7–29.3%) (n = 1463) | 16.7% (n = 108) | 19.1% (n = 318) | 35.6% (n = 291) | 25.4% (n = 677) | 59.4% (n = 69) |
|                                 | Open (Grade III only) | 10.3% (CI: 8.8–12.1%) (n = 1359) | 4.6% (n = 108) | 7.5% (n = 307) | 16.8% (n = 291) | 7.0% (n = 584) | 33.3% (n = 69) |
|                                 | Acute nonperiprosthetic | 98% | 97% | 97% | 94% | 99% | 100% |
|                                 | AO type A or C  |                  |                |                |                |                |                |
| In all treatment options, adjunctive screws and/or plates were used to fix the articular surface. *45 case series, 1 operative arm of an RCT, and 1 comparative study with 1 LISS and 1 rIMN arm.
†Primary Implant: blade plate = 41%, DCS = 33%, condylar buttress plate = 23%, others = 3%. Compression plating relates to techniques/implants that require compression of the implant to the femoral shaft-it does not relate to interfragmentary compression.
‡Not all baseline parameters are available for all studies. Therefore, the number of patients that a particular parameter is reported on is included in parentheses.

| TABLE 2. Results by Surgeons' Experience |
|-----------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Fractures Per Surgeon                   | ≥ 21            | < 21 or Unknown | RRR             | \( P \) |
| Total no. of series                     | 3              | 45              |                 | 0.749 |
| Total N                                | 182            | 1488            |                 | 0.064 |
| Articular                              | 59.3% (n = 182) | 57.9% (n = 1360) |                 | 0.392 |
| Severe articular (C3)                  | 26.9% (n = 182) | 20.7% (n = 1053) |                 | 0.013 |
| Open (Total)                           | 26.5% (n = 182) | 26.0% (n = 1281) |                 | 0.246 |
| Open (Grade III only)                  | 15.9% (n = 182) | 9.5% (n = 1177) |                 | 0.082 |
| Nonunions                              | 3.8%           | 6.3%            | 38% (RRR 71% to RRI 31%) | 0.046 |
| Fixation failure                       | 2.7%           | 3.5%            | 21% (RRR 68% to RRI 94%) | 0.828 |
| Deep infection                         | 2.2%           | 2.8%            | 22% (RRR 71% to RRI 115%) | 0.825 |
| Secondary surgical procedures          | 11.5%          | 17.6%           | 34% (RRR 1% to RRI 57%) | 0.046 |

Not all baseline parameters are available for all studies. Therefore, the number of patients that a particular parameter is reported on is included in parentheses. RRR indicates relative risk reduction; RRI, relative risk increase.
Are The Results of These Studies Valid?

The available literature includes only one randomized controlled trial comparing operative and non-operative treatments and no case-control study. All identified studies were observation studies (case series, cohort studies). There was 1 prospective cohort study and 45 case series.

The results need to be interpreted with caution because of the fact that the validity of observational studies is limited by the lack of a control group (case series), imbalances between comparison groups due to the lack of randomization (cohort studies), and potentially biased assessment of outcome measures due to lack of blinding.

Evidence-Based Pearl

Study identification of a specific topic of interest can be a difficult and time-consuming task. The 2 main resources for quickly finding articles with the highest level of evidence (Randomized Controlled Trials and systematic reviews) without any extended knowledge of search algorithms are the Cochrane database (www.cochrane.org) and the “clinical queries” function in PubMed (www.pubmed.org), which is accessible for free.

Use of multiple sources is advisable if the user wants to get more information or no highest-level evidence is available (eg, regular PubMed search, OTA abstract database search, AAOS abstract database search and review of bibliographies of identified articles). In any case, the key to successful and time-efficient study identification is to perform a targeted search that minimizes hits.
without missing the relevant articles. Understanding the search algorithms of each source is crucial for more extended searches (eg, PubMed operators like “AND,” “OR,” “NOT,” and search field tags like [MeSH], [ti], [au], [edat]).

Evidence-Based Bottom Line

On the basis of the current available evidence, we report the following:

- Operative versus Nonoperative Management of Distal Femoral Fractures
  
  Grade B (Evidence from RCT with methodological limitations)
  
  - Operative treatment results in a 32% reduction in the risk of poor results compared to nonoperative management.

- Type of Internal Fixation for Distal Femoral Fractures
  
  Grade C (Evidence from retrospective case series and 1 prospective comparative study)
  
  - No observed differences between implants in nonunions, infections, fixation failures, and revision surgeries.
  - Exploratory subgroup analyses suggest that submuscular locked fixators may reduce infection rates but at an increased risk of fixation failure and revision surgery compared to techniques that require compression of the implant to the femoral shaft (blade plate, dynamic condylar screw, nonlocking condylar buttress plate).
  - Surgeons with increased experience may significantly reduce the risk of revision surgery.

  Future studies should aim to prospectively compare implants in a randomized manner. Studies should be of sufficiently larger sample size to allow meaningful interpretation of their results.

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