

Treatment of acute distal femur fractures above a total knee arthroplasty

Systematic review of 415 cases (1981–2006)

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Background There is no consensus on the best treatment for periprosthetic supracondylar fracture.

Material and methods We systematically summarized and compared results of different fixation techniques in the management of acute distal femur fractures above a total knee arthroplasty (TKA). Several databases were searched (Medline, Cochrane library, OTA and AAOS abstract databases) and baseline and outcome parameters were abstracted.

Results We extracted data from 29 case series with a total of 415 fractures. The following outcomes were noted: a nonunion rate of 9%, a fixation failure rate of 4%, an infection rate of 3%, and a revision surgery rate of 13%. Retrograde nailing was associated with relative risk reduction (RRR) of 87% ($p = 0.01$) for developing a nonunion and 70% ($p = 0.03$) for requiring revision surgery compared to traditional (non-locking) plating methods. Point estimates also suggested risk reductions for locking plates, although these were not statistically significant (57% for nonunion, $p = 0.2$; 43% for revision surgery, $p = 0.23$) compared to traditional plating. RRRs for nonunion and revision surgery were also statistically significantly lower for retrograde nailing and locking plates compared to nonoperative treatment.

Interpretation Modern-day treatment methods are superior to conventional treatment options in the management of distal femur fractures above TKAs. The results should be interpreted with caution, due to the lack of randomized controlled trials and the possible selection bias in case series.

There have been no accurate estimates of the prevalence and incidence of femur fractures around total knee arthroplasties. Data from the Mayo Clinic total joint registry (Rochester, MN) including 19,810 total knee procedures with variable follow-up, suggested a femur fracture rate of 1.3% with 4 out of every 5 fractures occurring in women (Berry 1999). Although a periprosthetic supracondylar femur fracture is a rare event, it is expected that orthopedic surgeons will encounter these fractures more often as the number of total knee arthroplasties increases with time.

A wide variety of treatments have been described in the literature, from closed nonoperative treatment, external fixators, to open/closed reduction-internal fixation with different implants such as compression plates, blade plates, locking plates, and flexible or rigid intramedullary devices. However, there is no consensus on the ideal treatment for periprosthetic supracondylar fractures.

The purpose of this study was to conduct a systematic review in order to compare the results of different fixation techniques (nonoperative treatment, conventional non-locking plating techniques, retrograde intramedullary nailing, submuscular locked internal fixation, and external fixation) in the operative management of acute distal femur fractures around a total knee arthroplasty.

Material and methods

Eligibility criteria

All studies reporting on the treatment of at least 5 cases of a distal femur fracture above a total knee arthroplasty were considered. Articles dealing with revision arthroplasty as the treatment option were excluded. In all articles that were included, cases describing revision arthroplasty were also excluded. Only articles written in English or German were considered.

Study identification (search date: June 2006)

We searched the following databases: (1) Medline, (2) the Cochrane database, (3) the OTA online abstracts database of the 2004 and 2005 annual meetings, and (4) the AAOS online abstract database of the 2004 and 2005 annual meetings. Subsequently, the reference lists of articles that we identified were reviewed for additional articles.

Data analysis

The outcome parameters were defined as follows:

1. *Nonunion rate.* The nonunion rate included reported nonunions, secondary surgical procedures for delayed unions, infections leading to nonunion, and implant exchange before union. Fixation failures leading to an implant exchange before union were therefore included in the nonunion rate. Loosening of the femoral component was included in the fixation failure rate, but not the nonunion rate. Fixation failure after bony union was also excluded from the nonunion rate.

2. *Fixation failure rate.* The fixation failure rate included events that led to a secondary surgical procedure. This included screw loosening, implant cutout or migration, implant breakage leading to a nonunion, loosening of the femoral component, 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 included all infections except superficial infections not resulting in surgical debridement and pin infections in the external fixator group. Infections resulting in a nonunion also counted towards the nonunion rate.

4. *Secondary surgical procedures.* The secondary surgical procedure rate included any reported

secondary surgical procedure related to the distal femur fracture. This included partial (screw only) or complete implant removal and also patient's refusal of an indicated reoperation as determined by the surgeon. It did not include planned staged bone grafting in open fractures, planned irrigation and debridement, or external fixator removal in the external fixation group.

Outcome parameters as well as treatment option, sample size, average age, fracture type (displaced/non-displaced), percentage of open fractures, average follow-up (or minimum follow-up, if average follow-up was not reported), mechanism of injury (low- vs. high-energy) were extracted from each article, if they were reported. The results were stratified by the treatment option: nonoperative treatment, conventional plating techniques (blade plate, dynamic condylar screw, non-locking condylar buttress plate, and others), retrograde intramedullary nailing, locked internal fixation (LISS: less invasive stabilization system, and locking condylar plate) and other fixation techniques (screws, Rush rods, Ender nails, external fixation). The mean values were calculated for all fractures that were included and for each treatment option separately. All values were weighted by the sample size of each study. Outcome parameters between the nonoperative and the intramedullary group, the nonoperative and the locked-plating group, the conventional plating group and the intramedullary group, and lastly, the conventional plating group and the locked plating group were compared using Fisher's exact test. Averages and 95% confidence intervals of the corresponding relative risks and relative risk reductions were calculated.

Results

We identified 32 case series. There were no comparative studies—either randomized or non-randomized. Data extraction in a meaningful way was not possible in three articles (Aaron and Scott 1987, Figgie et al. 1990, Lombardi et al. 1995). Ultimately, 29 articles were included in this systematic review. A total of 415 fractures that were treated either nonoperatively (Short et al. 1981, Sisto et al. 1985, Cain et al. 1986, Merkel and Johnson 1986, Culp et al. 1987, Bogoch et al. 1988, Nielsen et al.

Table 1. Outcomes for different treatment options

Implant/technique	Total	Nonoperative	Conventional plating ^a	rIMN	Locked plating ^b	Other ^c
Total no. of series	29	10	17	9	5	10
Total n	415	121	123	65	57	49
Mean follow-up (months)	35	38	31	27	15	66
Studied n ^d	(369)	(114)	(118)	(58)	(40)	(39)
Outcome parameter						
Nonunions	37/415 = 8.9%	14/121 = 12%	15/123 = 12%	1/65 = 1.5%	3/57 = 5.3%	4/49 = 8.2%
95% CI (%)	(6.5–12.0)	(7.0–19)	(7.5–19)	(0.3–8.2)	(1.8–14)	(3.2–19)
Fixation failure	16/415 = 3.9%	2/121 = 1.7%	9/123 = 7.3%	1/65 = 1.5%	2/57 = 3.5%	2/49 = 4.1%
95% CI (%)	(2.4–6.2)	(0.5–5.8)	(3.9–13)	(0.3–8.2)	(0.9–12)	(1.1–14)
Deep infection	13/415 = 3.1%	1/121 = 0.8%	7/123 = 5.7%	0/65 = 0.0%	3/57 = 5.3%	2/49 = 4.1%
95% CI (%)	(1.8–5.3)	(0.1–4.5)	(2.7–11)	(0.0–5.6)	(1.8–14)	(1.1–14)
Secondary proc.	54/415 = 13%	22/121 = 18%	19/123 = 15%	3/65 = 4.6%	5/57 = 8.8%	5/49 = 10%
95% CI (%)	(10–17)	(12–26)	(10–23)	(1.6–13)	(3.8–19)	(4.4–22)

CI: 95% confidence interval; rIMN: retrograde intramedullary nail.

^a Primary implant: dynamic condylar screw = 24%, blade plate = 20%, condylar buttress plate = 13%, double plating = 13%, other = 40%.

^b Primary implant: less invasive stabilization system = 56%, locking condylar plate = 44%.

^c Primary implant: rush rods = 57%, external fixation = 20%, Ender's nails = 10%, screws = 4%, other = 8%.

^d Not all baseline parameters are available for all studies. Thus, the number of patients that a particular parameter is reported on is included in parentheses.

1988, Cordeiro et al. 1990, Garnavos et al. 1994, Moran et al. 1996), operatively by conventional non-locking plating techniques (Short et al. 1981, Sisto et al. 1985, Cain et al. 1986, Merkel and Johnson 1986, Culp et al. 1987, Bogoch et al. 1988, Nielsen et al. 1988, Cordeiro et al. 1990, Healy et al. 1993, Zehntner and Ganz 1993, Garnavos et al. 1994, Moran et al. 1996, Oschner and Pfister 1999, Weber and Peter 1999, Al-Shawi et al. 2002, Wang and Wang 2002, Althausen et al. 2003, Bezwada et al. 2004), retrograde intramedullary nailing (Culp et al. 1987, Garnavos et al. 1994, McLaren et al. 1994, Weber et al. 2000, Wick et al. 2001, 2004, Althausen et al. 2003, Bezwada et al. 2004, Gliatis et al. 2005), locked submuscular plating techniques (Kregor et al. 2001, Althausen et al. 2003, Wick et al. 2004, Raab and Davis 2005, Ricci et al. 2006) or other treatment options (Cain et al. 1986, Merkel and Johnson 1986, Culp et al. 1987, Bogoch et al. 1988, Nielsen et al. 1988, Biswas et al. 1992, Ritter et al. 1995, Weber and Peter 1999, Althausen et al. 2003, Hayakawa et al. 2003). Some manuscripts reported on two or more treatment options.

The data from all articles were pooled. The average follow-up was 35 months (based on n = 369; follow-up was not reported for the remaining 46

fractures). The average age of the patients was 69 years. 78% of the fractures were displaced (based on n = 301). Only 1 fracture was described as open; all other fractures were either closed or it was not stated whether they were open or closed. 94% of the patients sustained the fracture due to a low-energy mechanism, whereas in 7% of the fractures the injury was caused by a high-energy mechanism (based on n = 383). Overall, the average nonunion rate was 9%, the fixation failure rate was 4%, the deep infection rate was 3%, and the average secondary surgical procedure rate was 13%.

The relative risk of developing a nonunion or the need for an additional surgery procedure was significantly higher when nonoperative treatment or conventional plating methods were chosen, rather than retrograde intramedullary nailing (Table 1). The relative risk of developing a nonunion was reduced by 87% (95%CI: 7–98) (p = 0.01) when retrograde intramedullary nailing was performed, as opposed to conventional plating. The corresponding relative likelihood of requiring a secondary surgical procedure was reduced by 70% (95%CI: 3–91) (p = 0.03).

Point estimates also suggested a 57% (95% CI: -43 to 87) lower nonunion rate (p = 0.19) and a 43%

Table 2. Relative risks

	Nonunion	SSPs
Nonoperative vs. locked plating	14/121 vs. 3/57	22/121 vs. 5/57
RR (95% CI)	2 (0.7–7.3)	2 (0.8–5.2)
P-value	0.27	0.12
Nonoperative vs. IM nailing	14/121 vs. 1/65	22/121 vs. 3/65
RR (95% CI)	8 (1.0–56)	4 (1.2–13)
P-value	0.02	0.01
Conventional vs. locked plating	15/123 vs. 3/57	19/123 vs. 5/57
RR (95% CI)	2 (0.7–7.7)	2 (0.7–4.5)
P-value	0.2	0.3
Conventional plating vs. IM nailing	15/123 vs. 1/65	19/123 vs. 3/65
RR (95% CI)	8 (1.1–59)	3 (1.0–11)
P-value	0.01	0.03

RR: relative risk; SSPs: secondary surgical procedures; CI: 95% confidence interval.

(95% CI: -45 to 71) lower likelihood of requiring an additional surgical procedure ($p = 0.25$) when locked plating was performed rather than conventional (non-locked) plating techniques.

The absolute event rates (nonunion and secondary surgical procedure) in the locked plating and intramedullary nailing group were too low ($\text{all} \leq 5$) to allow a meaningful statistical comparison of these two groups.

Discussion

A distal femur fracture above a total knee arthroplasty constitutes a difficult treatment dilemma. Some of the problems or challenges associated with it include a short distal segment for fixation, osteoporotic bone, surgical exposure and blood loss, and the potential for varus collapse without both column support (Rorabeck and Taylor 1999). Surgical options include intramedullary devices, external fixators, fixed-angle devices (blade plates, dynamic condylar screws), condylar buttress plates, and—more recently—locking plates (internal fixators) that are typically placed in a submuscular manner.

Goals of treatment include returning the patient to his or her pre-injury level of function. From a surgical standpoint, ideally the technique should be minimally invasive, with the use of implants that respect the vascularity and biology of healing,

which are adaptable to various total knee arthroplasty designs, and which create a stable construct to permit immediate motion.

Historically, periprosthetic distal femur fractures were treated closed. Early plating techniques include condylar buttress plates, blade plates, and dynamic condylar screws. However, they usually require large surgical exposure and are associated with significant loss of blood. More modern techniques such as retrograde intramedullary nails and submuscular internal fixators have gained widespread acceptance

in recent years. Intramedullary devices are soft tissue friendly and require minimal surgical exposure, but they are not applicable to all designs of total knee arthroplasty. Unlike cruciate retaining prostheses, posterior stabilized knee designs are not amenable to retrograde nailing. Another pitfall with intramedullary devices is that they are limited with regard to distal purchase and fixation.

Locking plates (internal fixators) have numerous advantages, including the ability to be placed through limited exposure, and they offer the advantages of a multiple fixed-angle construct. One of the most significant benefits of the submuscular plating systems includes less injury to the vascular structures. In a study comparing submuscular plating with conventional open plating in 20 cadavers, Farouk et al. (1999) found no risk of injury to the vessels with the submuscular plating system, as opposed to 65% risk of vascular disruption with conventional plating techniques.

Over time, with acknowledgement of and respect for vascularity and the biology of healing, there has been evolution in fracture care. This evolution involves moving away from extensile approaches and rigid anatomic fixation to minimally invasive percutaneous plate osteosynthesis (MIPPO) and retrograde intramedullary nailing, and the results of this systematic review support this trend.

Limitations of this study

The literature that is available includes only obser-

vational studies. There have been no randomized or non-randomized comparative studies. The results must be interpreted with caution due to the fact that the validity of observational studies is limited by the lack of a control group and by potentially biased assessment of outcome measures due to lack of blinding. The lack of randomized controlled groups can lead to substantial selection bias, which limits the comparisons between groups; the subjects in one treatment group may be different from those in other treatment groups, e.g. in terms of age or fracture types. The validity of the secondary surgical procedure rate is limited by the varying length of follow-up.

Conclusion

Based on our findings, modern-day treatment methods (retrograde intramedullary nailing and submuscular locked plating) are superior to conventional treatment options—including nonoperative treatment and conventional (non-locking) plating methods (e.g. dynamic condylar screw, blade plate, and condylar buttress plate)—in the treatment of distal femur fractures above a total knee arthroplasty.

Based upon the evidence that is currently available, the following appears to be true: retrograde intramedullary nailing results in significantly lower nonunion rates and secondary surgical procedure rates than nonoperative treatment or conventional plating. Also, point estimates suggest that submuscular locked plating results in lower nonunion rates and secondary surgical procedure rates than nonoperative treatment or conventional plating; however, the results are not statistically significant.

Future studies should aim to compare implants prospectively in a randomized manner. Such studies should be of sufficiently large sample size and should include functional outcome parameters to allow meaningful interpretation of the results.

Contributions of authors

DAH: manuscript preparation, literature research, data abstraction. PJK, PAC, BAL, AJ: critical manuscript revision. MZ: study design, literature research, data analysis, manuscript preparation.

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