REVIEW ARTICLE

Periprosthetic Distal Femur Fracture after Total Knee Arthroplasty: A Systematic Review

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This study was designed to itemize and analyze the classification of fracture types and their corresponding outcomes in an attempt to provide a better understanding of the current treatment methods. Two PubMed searches were performed using the words "periprosthetic distal femur fracture" and "periprosthetic supracondylar femur fracture" in studies that were published in the previous 10 years (2004–2014). Data from 41 articlesthat met the general inclusion criteria, were collected and categorized into fracture type and treatment method groupings. Healing outcome and complications were the two parameters used to analyze the data. Treatment techniques were grouped in the following categories: locking plate, non-locking plate, intramedullary nail/rod, screw, blade plate, cerclage wires, allograft, external fixation, revision arthroplasty, non-operative, and other. Classification systems by Lewis and Rorabeck, the Association for Osteosynthesis/Orthopedic Trauma Association (AO/OTA), Su *et al.*, Neer *et al.*, Kim *et al.*, Backstein *et al.*, and the Société Française de Chirurgie Orthopédique et Traumatologique were reported. In total 448 fractures were identified, of which Rorabeck type II was the most common fracture studied. The two most successful treatment options for periprosthetic distal femur fractures were locking plate (87%) and intramedullary nail/rod (84%). The most frequent complications associated with periprosthetic distal femur fractures included non/mal/delayed union and the need for revision. Locking plates used to treat Rorabeck type II fractures had a complication rate of 35% and those treated with intramedullary nailing had a higher complication rate of 53%. In conclusion, the most frequent type of periprosthetic distal femur fracture after total knee arthroplasty was Rorabeck type II. The most common treatments for these types of fractures are locked plating and intramedullary nailing, with similar healing rates of 87% and 84%, respectively. However, the complication rate for locked plating was lower than for intramedullary nailing.

Key words: Distal femur; Periprosthetic fracture; Systematic review; Total knee arthroplasty

Introduction

Total knee arthroplasty (TKA) is a common procedure performed in the elderly population. However, now that elderly patients with knee replacements are living longer and remaining active, fractures around knee replacements are becoming more prevalent. The rate of periprosthetic fractures after TKA is 0.3%–2.5%[1]. The most common periprosthetic fracture is that of the distal femur, although the fracture pattern can vary.

The most recent systematic review to explore periprosthetic distal femur fractures after TKA was conducted by Herrera *et al.* in 2008[2]. Their review evaluated previous studies to form a conclusion on the best method fortreatment for periprosthetic distal femur fractures after TKA. They reported that locking plates and retrograde intramedullary nailing produced the most successful results, with retrograde intramedullary nailing slightly outperforming locking plates. Since the rate of periprosthetic fractures will presumably continue to rise, continuing research is needed to better understand and treat these types of fractures. Additionally, because each patient and fracture is unique, a more exhaustive approach may be advantageous.

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Evaluating specific treatment methods and specific fracture types may lead to a quicker and more reliable approach in treating periprosthetic distal femur fractures. To date, no literature attempting to link treatment methods with classification types of distal femur fracture has been published. Prompted by the absence of this kind of itemized information, this systematic review examines the literature on the treatment of periprosthetic distal femur fractures after TKA from the past 10 years (i) to organize the reported fracture data by classification type and treatment method; (ii) to determine the most common type of fracture; (iii) to determine the most common treatment method; and (iv) to find any relationships between fracture type and treatment method with regard to outcome.

Methods

Two PubMed searches were performed using the words "periprosthetic distal femur fracture" and "periprosthetic supracondylar femur fracture." The searches ended on July 8, 2014. Only articles in the English language that were published in the previous 10 years (2004–2014) were included. To be included, each article needed to meet the following general criteria: a study of distal femur fractures after a TKA using any treatment method(s) in which radiological and functional outcomes were analyzed. In order to maintain consistency, articles that examined secondary TKA or secondary distal femur fractures were not used. Additionally, studies that met our criteria but also involved patients with tibia fractures, patella fractures, total hip arthroplasties or other circumstances were included, as long as the individual results for each patient with a distal femur fracture could be identified. Patients without a distal femur fracture after TKA were excluded, as were patients with "floating" total knee prostheses. Review articles were not included.

Data were collected and organized using Microsoft Excel spreadsheets. Each article was thoroughly read and reviewed multiple times throughout the data collection process. The total number of patients and fractures excluded the patients who had died or were lost to follow up, but only if the patient's fracture(s) could be pinpointed to a specific classification.

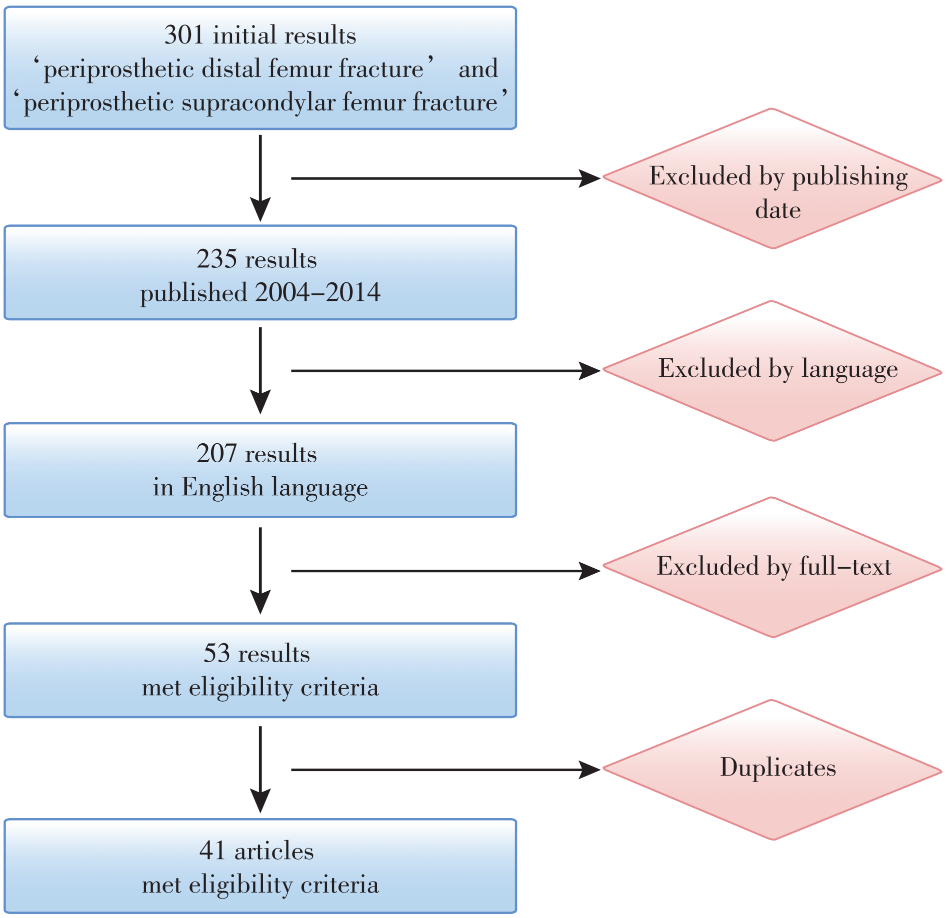

Fig. 1 Flow chart illustrating the process of including and excluding studies.

TABLE 1 Overview of selected articles

Authors	Patients (*n*)	Fractures (*n*)	Classification system	Treatment method(s)	Successful union (%)
Ha *et al.*[3]	14	14	Rorabeck	Locking plate	100
Jassim *et al.*[4]	10	10	Rorabeck	Other	100
Agarwal *et al.*[1]	15	15	Rorabeck	Locking plate	100
				Revision arthroplasty	
				Non-operative	
Gondalia *et al.*[5]	42	42	AO/OTA	Locking plate	71
				Intramedullary nail/rod	
Saidi *et al.*[6]	23	23	Backstein	Allograft	96
				Other	
Meneghini *et al.*[7]	85	85	Rorabeck	Locking plate	84
				Intramedullary nail/rod	
Lee *et al.*[8]	25	25	Rorabeck	Intramedullary nail/rod	100
Chen *et al.*[9]	35	36	Not reported	Other	-
Singh and Bhalodiya[10]	23	23	Rorabeck	Locking plate	78
				Non-locking plate	
				Non-operative	
Ries and Marsh[11]	2	2	AO/OTA	Locking plate	100
Lizaur-Utrilla *et al.*[12]	28	28	Rorabeck	Locking plate	89
				Intramedullary nail/rod	
				Screw	
				Revision arthroplasty	
Kilicoglu *et al.*[13]	16	16	Neer	Locking plate	100
				Intramedullary nail/rod	
Ozcan *et al.*[14]	1	2	Rorabeck	Locking plate	100
Ries *et al.*[15]	20	20	AO/OTA	Locking plate	89
Aldrian *et al.*[16]	86	86	Su	Locking plate	88
				Intramedullary nail/rod	
Bae *et al.*[17]	32	33	Rorabeck	Locking plate	73
				Non-locking plate	
Gavaskar *et al.*[18]	20	20	Rorabeck	Locking plate	95
Horneff *et al.*[19]	63	63	Rorabeck	Locking plate	81
				Intramedullary nail/rod	
Hou *et al.*[20]	52	52	AO/OTA	Locking plate	75
				Intramedullary nail/rod	
Jeavons *et al.*[21]	1	1	Rorabeck	Other	100
Hoffmann *et al.*[22]	35	36	AO/OTA	Locking plate	92
Ebraheim *et al.*[23]	27	27	not reported	Locking plate	89
Pot *et al.*[24]	1	1	not reported	Other	100
Vallier and Immler[25]	70	71	AO/OTA	Locking plate	72
				Blade plate	
Ehlinger *et al.*[26]	15	16	SOFCOT	Locking plate	94
Streubel *et al.*[27]	61	61	AO/OTA	Locking plate	85
Mortazavi *et al.*[28]	16	18	Kim	Other	100
Beris *et al.*[29]	3	3	Rorabeck	External fixation	100
Platzer *et al.*[30]	37	37	Su	Locking plate	89
				Intramedullary nail/rod	
				Revision arthroplasty	
				Non-operative	
Han *et al.*[31]	7	8	Rorabeck	Intramedullary nail/rod	100
Kolb *et al.*[32]	21	21	AO/OTA	Blade plate	95
Norrish *et al.*[33]	15	16	not reported	Locking plate	92
Chettiar *et al.*[34]	13	14	not reported	Intramedullary nail/rod	100
Large *et al.*[35]	50	50	Rorabeck	Locking plate	64
				Non-locking plate	
				Intramedullary nail/rod	
				Screw	
				Blade plate	
Fulkerson *et al.*[36]	18	18	not reported	Locking plate	94
Ricci *et al.*[37]	20	22	AO/OTA	Locking plate	86
Hurson *et al.*[38]	1	1	not reported	External fixation	100
Srinivasan *et al.*[39]	6	6	AO/OTA	Revision arthroplasty	100
Gliatis *et al.*[40]	9	10	Rorabeck	Intramedullary nail/rod	100
Bezwada *et al.*[41]	30	30	not reported	Locking plate	93
				Intramedullary nail/rod	
Kassab *et al.*[42]	10	10	Rorabeck	Allograft	90

AO/OTA, Association for Osteosynthesis/Orthopedic Trauma Association; SOFCOT, Société Française de Chirurgie Orthopédique et Traumatologique.

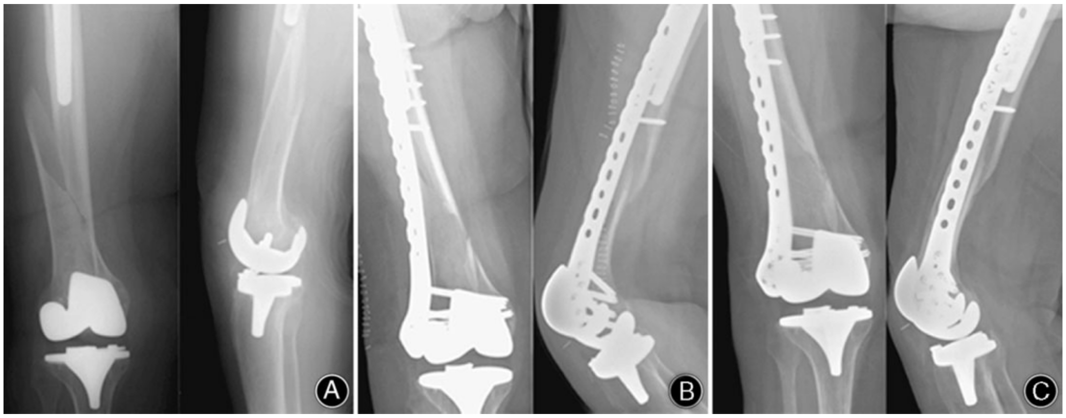

Fig. 2 Periprosthetic distal femur fractures (Su type I, Rorabeck type I) was treated with a distal femoral locking plate that spanned the entire interprosthetic zone. (A) preoperative, (B) postoperative day one, (C) union and full-weight bearing at 17 weeks.

Healing outcome and complications were the two parameters used to analyze the data. Healing outcome referred to the state of the fracture's bony union, such as a malunion, nonunion, or successful union. A successful healing outcome excluded a malunion, nonunion, or hardware failure, unless stated otherwise by the authors. Complications were further divided into the following categories: infection, hardware/implant failure, nonunion/malunion/delayed union, revision, bone grafting, and other.

Results

The searches for periprosthetic distal femur fracture and periprosthetic supracondylar femur fracture for articles published within the previous 10 years yielded 301 results (Fig. 1). Of these, 41 articles met the remaining criteria, generating 1054 patients with 1068 fractures. Nine studies did not report all or some of the fractures, leaving 142 fractures unclassified. An overview of the 41 articles, showing the overall union rate of each study, is presented in Table 1.

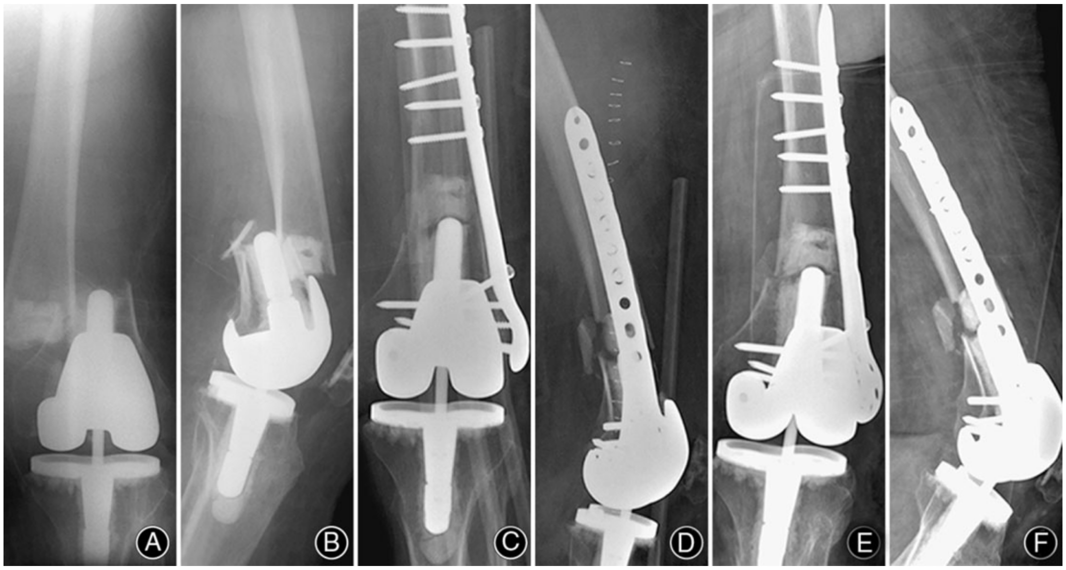

Fig. 3 Periprosthetic distal femur fractures (Su Type II, Rorabeck type II) were treated with a distal femoral locking plate showing; (A) preoperative anteroposterior radiograph; (B) preoperative lateral radiograph; (C) postoperative anteroposterior radiographs demonstrating acceptable reduction of the periprosthetic distal femur fracture treated with reverse locking plate fixation; (D) postoperative lateral radiograph; (E) postoperative anteroposterior radiographs at 3 months demonstrating minimal callus formation and sustained fracture reduction in weight bearing patient; (F) postoperative lateral radiograph at 3 months.

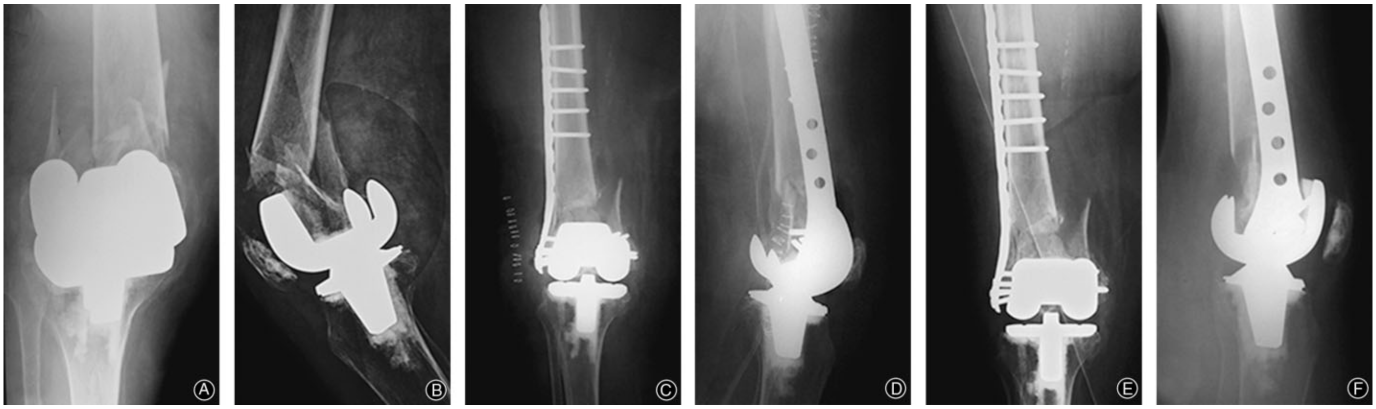

Fig. 4 Periprosthetic distal femur fracture (Su type III, Rorabeck type III) was treated with a distal femoral locking plate showing: (A) preoperative anteroposterior radiograph; (B) preoperative lateral radiograph; (C) postoperative anteroposterior radiographs; (D) postoperative lateral radiograph; (E) postoperative anteroposterior radiographs at 3 months; (F) postoperative lateral radiograph at 3 months.

TABLE 2 Fractures (*n*)

Classification system	Subclassification	Fractures *n* = 1068	Fractures with sufficient data: Healing outcome *n* = 488	Fractures with sufficient data: Complications *n* = 448
Rorabeck	Type I	12	10	7
	Type II	363	345	310
	Type III	15	15	13
AO/OTA	32A	10	0	0
	32B	3	0	0
	33A	39	0	0
	33A1	70	5	5
	33A2	67	16	16
	33A3	108	27	27
	33B2	2	2	2
	33C1	11	0	0
	33C2	20	1	1
Su	Type I	43	0	0
	Type II	76	0	0
	Type III	14	10	10
Backstein	F2	23	23	23
Kim	Type III	18	18	18
Neer	Type II	13	13	13
	Type III	1	1	1
	Type IIII	2	2	2
SOFCOT	B1	6	0	0
	C	10	0	0
Unclassified	—	142	0	0

AO/OTA, Association for Osteosynthesis/Orthopedic Trauma Association; SOFCOT, Société Française de Chirurgie Orthopédique et Traumatologique.

Treatment techniques were grouped in the following categories: locking plate, non-locking plate, intramedullary nail/rod, screw, blade plate, cerclage wires, allograft, external fixation, revision arthroplasty, non-operative, and other. Classification systems by Lewis and Rorabeck, the Association for Osteosynthesis/Orthopedic Trauma Association (AO/OTA), Su *et al*., Kim *et al*., Neer *et al*., Backstein *et al*., and the Société Française de Chirurgie Orthopédique et Traumatologique (SOFCOT) were reported[43–49] (Figs 2–4).

Many articles contained ambiguous data, so not all fractures could be indentified with their corresponding specific healing outcome and/or complication(s). Of the 1068 total fractures, 488 could be matched with their corresponding healing outcome and 448 could be matched with their corresponding complications (Table 2). The most common documented fracture type was Rorabeck type II (n = 363). There was not enough information to determine either healing outcome or complication(s) of AO/OTA 32A, 32B, 33A, and 33C1; Su type I and II; SOFCOT B1 and C.

Each fracture with adequate reported data was grouped based on its classification and method of treatment. The success rate of the 488 fractures is reported in Table 3. The largest sample sizes were of Rorabeck type II fractures treated with a locking plate and Rorabeck type II fractures treated with an intramedullary nail/rod. In all, 87% of fractures treated with a locking plate and 84% of fractures treated with an intramedullary nail/rod healed successfully.

The complications of the 448 fractures are reported in Table 4. The most frequent complications were non/mal/delayed union and revision, with 61 and 63 instances of each, respectively. The largest sample sizes were of Rorabeck type II fractures with a locking plate and Rorabeck type II fractures treated with an intramedullary nail/rod. Fractures treated with a locking plate had a complication rate of 35% and fractures

TABLE 3 Healing outcome (*n*)

Classification	Subclassification	Method	Successful healing outcome (%)
Rorabeck	Type I	Locking plate	2/2 (100)
		Intramedullary nail/rod	1/1 (100)
		Screw	1/1 (100)
		External fixation	1/1 (100)
		Non-operative	3/5 (60)
	Type II	Locking plate	157/180 (87)
		Non-locking plate	15/26 (58)
		Intramedullary nail/rod	102/122 (84)
		Screw	7/10 (70)
		Blade plate	3/4 (75)
		External fixation	2/2 (100)
		Other	1/1 (100)
	Type III	Allograft	9/10 (90)
		Revision arthroplasty	4/5 (80)
AO/OTA	33A1	Locking plate	3/3 (100)
		Blade plate	1/1 (100)
		Revision arthroplasty	1/1 (100)
	33A2	Locking plate	8/8 (100)
		Blade plate	7/7 (100)
		Revision arthroplasty	1/1 (100)
	33A3	Locking plate	10/13 (77)
		Blade plate	12/13 (92)
		Revision arthroplasty	1/1 (100)
	33B2	Revision arthroplasty	2/2 (100)
	33C2	Revision arthroplasty	1/1 (100)
Su	Type III	Other	10/10 (100)
Backstein	F2	Allograft	6/7 (86)
		Other	16/16 (100)
Neer	Type II	Locking plate	7/7 (100)
		Intramedullary nail/rod	5/6 (83)
	Type III	Intramedullary nail/rod	1/1 (100)
	Type IIII	Locking plate	2/2 (100)
Kim	Type III	Other	18/18 (100)

AO/OTA, Association for Osteosynthesis/Orthopedic Trauma Association.

TABLE 4 Complications (*n*)

Classification	Subclassification	Method	Fractures	Complications						
				Infection	Hardware/implant failure	Non/mal/delayed union	Revision	Bone grafting	Other	Total (%)
Rorabeck	Type I	Locking plate	2	0	0	0	0	0	0	0 (0)
		Screw	1	0	0	0	0	0	0	0 (0)
		External fixation	1	1	0	0	0	0	0	1 (100)
		Non-operative	3	0	0	2	0	0	0	2 (67)
	Type II	Locking plate	169	7	2	23	12	7	8	59 (35)
		Non-locking plate	26	1	1	10	8	4	6	30 (115)
		Intramedullary nail/rod	98	1	6	19	21	1	4	52 (53)
		Screw	10	0	0	3	3	1	0	7 (70)
		Blade plate	4	1	0	0	0	0	1	2 (50)
		External fixation	2	1	0	0	0	0	0	1 (50)
		Other	1	0	0	0	0	0	0	0 (0)
	Type III	Allograft	10	1	0	1	3	1	1	7 (70)
		Revision arthroplasty	3	0	0	1	0	0	0	1 (33)
AO/OTA	33A1	Locking plate	3	0	0	0	0	0	0	0 (0)
		Blade plate	1	0	0	0	0	0	0	0 (0)
		Revision arthroplasty	1	0	0	0	0	0	0	0 (0)
	33A2	Locking plate	8	0	0	0	0	0	0	0 (0)
		Blade plate	7	0	0	0	1	0	0	1 (14)
		Revision arthroplasty	1	0	0	0	0	0	0	0 (0)
	33A3	Locking plate	13	2	4	1	0	0	4	11 (85)
		Blade plate	13	1	1	0	2	5	2	11 (85)
		Revision arthroplasty	1	0	0	0	0	0	0	0 (0)
	33B2	Revision arthroplasty	2	0	0	0	0	0	1	1 (50)
	33C2	Revision arthroplasty	1	0	0	0	0	0	0	0 (0)
Su	Type III	Other	10	2	0	0	0	0	4	6 (60)
Backstein	F2	Allograft	7	1	0	1	1	0	0	3 (43)
		Other	16	2	0	0	2	0	1	5 (31)
Neer	Type II	Locking plate	7	0	0	0	0	0	0	0 (0)
		Intramedullary nail/rod	6	0	0	0	0	0	1	1 (17)
	Type III	Intramedullary nail/rod	1	0	0	0	0	0	0	0 (0)
	Type IIII	Locking plate	2	0	0	0	0	0	0	0 (0)
Kim	Type III	Other	18	0	0	0	10	0	0	10 (56)
Total			448	21	14	61	63	19	33	211 (47)

AO/OTA, Association for Osteosynthesis/Orthopedic Trauma Association.

treated with an intramedullary nail/rod had a complication rate of 53%.

Discussion

Several treatment methods, both conservative and surgical, are currently used to treat periprosthetic distal femur fractures after TKA. However, due to variations in individual patient health and distal femur fracture patterns, the optimal method of treatment remains controversial and no gold standard of treatment has been established. The current selection of treatment methods may not provide a one size fits all solution. Instead, treatment methods may show successful outcomes when coupled with a specific fracture pattern. Therefore, the major goal of this study was to identify the most successful treatment methods for specific fracture types by examining the past literature.

Distal femur fractures can be categorized by different systems that focus on different characteristics. In this study, the classification systems developed by Rorabeck and AO/OTA were used most frequently, with 390 fractures classified under the Rorabeck system and 330 classified under the AO/OTA system. The Rorabeck classification system emphasizes the stability of the knee prosthesis and the displacement of the fracture[43]. The AO/OTA classification system focuses on the location of the fracture on the distal femur and the complexity of the fracture pattern[44]. The most common subclassification was Rorabeck type II, with 363 fractures. A Rorabeck type II fracture is labeled as a displaced fracture with a stable prosthesis[43].

The popularity of the Rorabeck and AO/OTA systems may lie in their concision and simplicity, although the Rorabeck system may predominate because it includes prosthesis stability. The other classification systems used in the selected literature focused on features such as bone amount, bone quality, and reducibility. While these are important factors to consider when treating fractures, these systems do not emphasize the fracture's displacement or pattern, which may limit their widespread use. A classification system that encompasses all these features may be beneficial. Creating a system to include key features, such as fracture displacement and pattern, as well as other supporting features, may provide detailed classifications that can match each patient's unique condition. Therefore, instead of a universal treatment method, different methods that treat different clasees of fracture may be more effective.

Locked plating and intramedullary nailing are currently the most common methods of treatment, as reflected in this study, due to their minimally invasive surgical technique. Rorabeck type II fractures treated with a locking plate or intramedullary nail/rod had similarly successfully healing rates of 87% and 84%, respectively. Nine articles, totaling 461 fractures, in our study directly compared locked plating and intramedullary nailing. Five articles found no overall advantage to either method, while three articles supported locked plating and one article favored nailing[5,7,13,16,19,20,30,35,41].

Although the healing rate for Rorabeck type II fractures between locked plating and the intramedullary nail/rod was similar, the complication rates differed. The complication rate for the intramedullary nail/rod was 18% higher than for locked plating. The two most frequent complications were non/mal/delayed union and revision, which seems reasonable as revision usually follows a malunion or nonunion.

There were several limitations to this study. Since data from 41 articles were compiled there was a lack of consistent standards from study to study. This included different brands of equipment being used, fracture classifications judged by different people, and different definitions of medical terms. In addition, each article was retrospective in nature and most lacked a control group. This study's detailed breakdown of each fracture resulted in small sample sizes for most of the groups in the classification and subclassification types. Additionally, the lack of comprehensive data for each fracture limited our sample sizes.

Conclusion

The most frequent type of periprosthetic distal femur fracture after TKA is Rorabeck type II. The most common treatments for these types of fractures are locked plating and intramedullary nailing, with similar healing rates of 87 and 84%, respectively. However, the complication rate for locked plating was lower than for intramedullary nailing.

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