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Review Article

Interprosthetic Femur Fractures: Systematic Review

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Objectives

Interprosthetic femur fractures (IFF) present unique challenges to orthopaedic surgeons due to the preexisting implants in place, oftentimes advanced age and poor bone quality. Through the development of specific implants and improvement of fixation principles, management of this rare—yet growing—fracture pattern has progressed in recent decades to improve patient outcomes. This study's aim was to identify patient-related outcomes after undergoing ORIF of interprosthetic femur fractures, including time to union,

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a I am a current resident at Maimoninides Medical Center in Brooklyn, NY. My interest in Orthopedic Trauma surgery was the impetus for further elucidating the complex treatment options involved with this project. I look forward to spending more time researching this complex fracture pattern. I would like to thank the senior authors on this paper for their continued guidance and help in bringing this information together.

Conflicts of Interest Statement for Dr. Golub

b Mitchell Ng is co-founder and managing partner of Thessalus Capital, a healthcare investment firm featured in Forbes, Bloomberg, and CNBC. He is currently an orthopaedic surgery resident at Maimonides Medical Center in Brooklyn, NY. He is also a medical affairs consultant at Ferghana Partners Group, an investment bank specializing in life sciences and specialty chemicals. He has published over 40 manuscripts, 70 posters/podiums, and 3 book chapters. Dr. Ng received his B.A. from Princeton University, majoring in molecular biology and graduating with honors. He received his M.D. from Case Western School of Medicine, where he graduated with honors in research.

Connect with Dr. Passias on LinkedIn

Conflicts of Interest Statement for Dr. Ng

c Visit the AAHKS Website

Conflicts of Interest Statement for Dr. Vakharia

d Dr. Kang's practice focuses on the treatment of traumatic injuries to the musculoskeletal system in both adults and adolescents. Dr. Kang has been involved in multiple research projects, received several grants, and published numerous scientific articles pertaining to Orthopedic Surgery. Currently, Dr. Kang serves as the Director of Orthopedic Trauma at Maimonides, a level 1 trauma center. He oversees the trauma service and strives for the optimal treatment of injured patients requiring Orthopedic services. Dr. Kang is also actively involved in resident and medical student education, serving as faculty for the Orthopedic Surgery residency program. Dr. Kang is committed to providing the highest level of care and expertise for his patients. He will provide both surgical and non-surgical services for those with upper or lower extremity injuries, pelvic/acetabular trauma, infections, and post-traumatic or degenerative disorders.

Visit Dr. Kang's page on the Maimonides Health website

Conflicts of Interest Statement for Dr. Kang

e Dr. Lisa Cannada is an Orthopedic Trauma Surgeon from Jacksonville, FL, affiliated with Novant Health & the Hughston Clinic. Lisa completed a term on the American Academy of Orthopaedic Surgeons BOD as the first female Chair of the Board of Specialty Societies. She is a member of the Orthopaedic Trauma Association and she served on the OTA Board of Directors and was active in numerous committees, including chair of the Fellowship Match committee and developing the match process for fellows in all disciplines of orthopaedic surgery. She developed the Young Practitioners Forum and the Women in Trauma program. She also served as a president of the Ruth Jackson Orthopaedic Society. She edited and produced the RJOS "Guide for Women in Orthopaedic Surgery" and the "Guide for Medical Students in Orthopaedic Surgery". She is currently chair of the Development Committee and on the RJOS BOD. Lisa is also on the Mid America Orthopaedic Association & the Southeast Fracture Consortium BOD. Education is a passion. Dr. Cannada is very involved in providing mentorship at all levels. Her clinical expertise includes the mangled extremity, polytrauma patients and complex fractures. She is interested in clinical outcomes research and diversity in orthopaedics. She has over 170 publications and 250 presentations. She is a founding member of #SpeakUpOrtho.

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Conflicts of Interest Statement for Dr. Cannada

change in pre-operative ambulatory status, malunion/nonunion, surgical site infections, and revisions.

Data sources

A systematic review of published literature was conducted on Pubmed/MEDLINE and Cochrane Library databases for English language papers published with 12 studies meeting inclusion/exclusion criteria.

Study selection

Studies providing quantitative data comparing time to union, change in ambulatory status, surgical site infections, malunion/nonunion, revisions, and one-year mortality were used in the analysis. Studies lacking quantitative data were excluded.

Data extraction

12 studies were included in this systematic review and graded by MINOR to identify potential biases. The aforementioned patient outcomes were calculated as mean values, ranges, and percentages.

Data synthesis

Time to union averaged 20.2 (range 6-28) weeks with roughly 18% of patients experiencing a decline in pre-operative ambulatory status. It was found 1.3% of patients experienced surgical site infections that were treated successfully either operatively or nonoperatively. Malunions and nonunions occurred in 1.63% and 6.12% of cases, respectively. Revisions were necessary in 12.6% of cases due to malunion, nonunion, and hardware failure. The one-year mortality rate was 12.8%.

Conclusion

Our review demonstrates that interprosthetic femur fractures continue to pose significant challenges in their treatment to both patients and orthopaedic surgeons. With the expected continued growth in the number of primary total hip and total knee arthroplasty performed annually, the incidence of interprosthetic femur fractures will continue to rise. Full femur spanning locked plating is currently the standard of care in fracture patterns with stable prostheses.

Level of Evidence

Therapeutic Level III

INTRODUCTION

In the United States, there are >700,000 total knee arthroplasties (TKA) and >300,000 total hip arthroplasties (THA) performed annually, with projected increases to >1.25 million and >600,000 cases by 2030, respectively (Wolford et al. 2015; Williams, Wolford, and Bercovitz 2015; Sloan, Premkumar, and Sheth 2018). Fractures between ipsilateral total knee arthroplasty and total hip arthroplasty are known as interprosthetic femur fractures (IFF). These fractures occur most frequently in the supracondylar region of the distal femur due to increased stress concentration surrounding TKA components (Mamczak et al. 2010). With the increasing incidence of ipsilateral arthroplasty procedures, it can be concluded that the rate of interprosthetic femur fractures will also rise. Studies have demonstrated that the incidence of periprosthetic proximal femur fractures is roughly 3-4%, and the incidence of periprosthetic distal femur fractures is up to 5.5% (Della Rocca, Leung, and Pape 2011; Benkovich et al. 2019; Abdel et al. 2016; Ramavath et al. 2020). This percentage may increase up to 30% in cases of revision total knee arthroplasty (Tosounidis and Giannoudis 2015).

Despite the large numbers of primary arthroplasty procedures performed, the incidence of IFF is rare. While previous studies have reported that this fracture pattern most commonly occurs in elderly women, few articles have attempted to report on the incidence of this fracture pattern. Considering IFFs more commonly occur in elderly and osteoporotic patients, as well as in cases of revision surgery, the primary goals of care include stable fracture fixation to allow for union and a well-aligned femur to optimize function (Scolaro and Schwarzkopf 2017; Sah et al. 2010; Soenen et al. 2011). Treatment options include revision arthroplasty if fractures are associated with loose prostheses or total femur replacement in the setting of severe bone loss. However, in the setting of well-fixed implants, ORIF with locked plating is advantageous due to the ability to use long plates and to preserve surrounding soft tissues without excessive periosteal stripping (Sah et al. 2010). Due to the paucity of available literature on interprosthetic femur fractures, the goal of this meta-analysis and systematic review is to evaluate union rate, change in preoperative ambulation status, complications including malunions/nonunions, surgical site infections, and revisions, and one-year mortality in patients undergoing ORIF of interprosthetic femur fractures.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to conduct this systematic review (Vrabel 2015). PubMed/MEDLINE and Cochrane Library database searches for all publications on interprosthetic femur fractures were performed using the search terms "interprosthetic femur fracture" in combination with the Boolean operators "AND" or "OR." Three reviewers (I.G., M.N., R.V.) performed the searches and determined the relevance of articles by reviewing the title and abstract of each article. Inclusion eligibility was subsequently determined by reviewing the title and corresponding abstract for each article; those meeting the initial eligibility were further screened based on a full-text review of the articles.

STUDY SELECTION

Studies that presented quantitative data on union, ambulation status, surgical site infection, malunion/nonunion, and revision rate in patients who underwent fixation for interprosthetic femur fractures were included in this systematic review. Studies that lacked quantitative data were excluded from this study. Articles were reviewed together (I.G, M.N, and R.V.). If a consensus could not be reached on article inclusion, the senior author (L.C.) was included, and a final decision was made. Studies were evaluated if they were published up to November 1, 2021.

DATA EXTRACTION

Studies meeting inclusion criteria were tabulated in Microsoft Excel (Microsoft, Redmond, WA). Title, author, year of publication, journal, type, evidence level, sample size, time to union, revision rate, number of malunions/nonunions, surgical site infection, final ambulation status, and mortality were exported. Single categorical analysis was performed with evaluations of means, range, and percentages for the respective patient outcomes. Some studies included a variety of treatments for interprosthetic femur fractures. Only information regarding patients undergoing ORIF was collected.

QUALITY ASSESSMENT

The Methodological Index for Non-Randomized Studies (MINORS) criteria were used to assess articles for quality by three reviewers (I.G., M.N., R.V.). Included studies were graded on the level of evidence using standard and pre-defined criteria (Vrabel 2015). Any score differences were discussed among reviewers, and a consensus was reached for final scoring.

RESULTS

GENERAL STUDY CHARACTERISTICS

The initial search yielded 28 studies meeting screening criteria, which underwent full review. Twelve studies met the inclusion criteria and were included in the analysis. All 12 studies were retrospective case-control studies which incorporated prospectively collected data with a level of evidence of at least III (Table 1). Three reviewers (I.G., M.N., R.V.) evaluated these studies to assess study quality with the inclusion of quantitative data.

TIME TO UNION

Time to union was reported on in 10 studies with a mean union time of 20.2 weeks (range 6-28 weeks) in a total of 208 patients (Table 1). No study demonstrated time to union below 13 weeks postoperatively. Mamczak et al. had the fastest time to union amongst analyzed studies with an average duration of 13 weeks, with the earliest union time at 6 weeks postoperatively. The longest average time to union amongst studies was presented by Platzer et al., with a mean time to union of 26 weeks.

POSTOPERATIVE CHANGE IN AMBULATORY STATUS

Of the 12 studies included in this analysis, 7 reviewed changes in preoperative ambulatory status. 20/109 patients (18.3%) in the analyzed studies experienced a decline from their preoperative ambulatory status after surgical fixation of their interprosthetic femur fractures (Table 1). The two largest samples sizes included Sah et al. who reported no cases of reported postoperative ambulatory changes, and Platzer et al. who reported six cases of postoperative ambulatory status declines (Platzer et al. 2011; Sah et al. 2010). Two additional studies, Hoffman et al. and Mittal et al., reported a total of 76 patients that returned to "weight-bearing as tolerated;" however, there was no mention of these patients requiring additional assistive devices postoperatively (Hoffmann, Lotzien, and Schildhauer 2016; Mittal, Poole, and Crone 2021).

MALUNION/NONUNION

Data regarding malunion/nonunion was reported in 12 studies totaling 245 patients. Malunion was defined in studies as healing with greater than 5 degrees of radiographic deformity in the sagittal or coronal planes. There were four patients who experienced malunions (1.63%) and 15 who experienced nonunions (6.12%) (Table 1) for a total of 7.75% of patients suffering from malunion/nonunion. The studies defined normal anatomic alignment as 6 degrees valgus of the distal femoral angle in the coronal plane and 0 degrees of angulation in the sagittal planes. Hence, malunion was generally defined as deformities greater than 5 degrees of normal and nonunion was defined as a lack of bridging callus across the original fracture site and increased pre-fracture pain with weightbearing. Of the malunion patients, three were reported by Mamczak et al., which included one patient with a 10-degree valgus deformity, one patient with a 10-degree flexion deformity, and one patient with a 9-degree recurvatum deformity (Mamczak et al. 2010). Ehlinger et al. reported on one patient with a 10-degree varus deformity that did not require reoperation (Ehlinger et al. 2013).

Of the nonunions, Hoffman et al. reported reoperation in three nonunion cases. One patient sustained a hardware failure secondary to nonunion and underwent treatment with autograft and revision internal fixation with dual plating. In their study, patients who sustained a nonunion were treated with longer plates ($p<0.05$). However, there was no statistically significant difference in working length. In addition, nonunion was not statistically significantly related to patient factors such as age, body mass index, osteoporosis, and diabetes, or to surgical factors including plate design, use of cerclage, or submuscular insertion (Hoffmann, Lotzien, and Schildhauer 2016). Mittal et al. similarly reported on three nonunions, all of which occurred with implant failure before four months after surgery. The first case was a patient who underwent fixation with a short working length plate (five holes) with accepted translation at the fracture site. At three months postoperatively, the plate broke at the level of the fracture with minimal callus formation appreciated. The patient underwent revision ORIF with a longer working length plate (eight holes) and restoration of mechanical axis, and achieved union within three months. The second patient in the study similarly underwent plate fixation with a short working length (four holes). Despite partial weight-bearing postoperatively, the plate broke at the level of the fracture with minimal callus formation at six weeks. Revision surgery included plating with a greater working length and despite lots of healing callus, that plate broke at two months postoperatively before union was achieved. This patient underwent a second revision and was united at five months after the second revision. The last nonunion in their study was a patient that was plated with a working length of four holes and noted to be malreduced with the TKA component fixed in varus and extension. This patient underwent two re-operations due to nonunion with fracture of plates on each occasion at which point the patient underwent plate-retrograde intramedullary nail (IMN) fixation that achieved union at six months postoperatively (Mittal, Poole, and Crone 2021). Bonnevialle et al. reported on four nonunions in their study and noted the likely reason for failure was due to a "short plate," which they defined as a plate length that did not bridge the femoral stem or reach the distal epiphysis. The study did not discuss any additional treatments the patients underwent (Bonnevialle et al. 2019). Lastly, Soenen et al. reported on four nonunions, three of which underwent revision to the total femur replacement. The last patient required two revisions with plating and bone graft due to the persistence of nonunion (Soenen et al. 2011).

SURGICAL SITE INFECTIONS

Twelve studies reported on surgical site infections that occurred postoperatively in patients undergoing ORIF of interprosthetic femur fractures (Table 1). A total of 230 patients were included, three (1.3%) of which experienced surgical site infections (SSIs). Mamczak et al. reported one superficial SSI which did not require reoperation (Mamczak et al. 2010). Bonnenvialle et al. reported two SSIs that underwent successful treatment with irrigation and debridement, and antibiotic therapy (Bonnevialle et al. 2019). The rate of SSIs in this study is significantly lower than in previous studies assessing SSI in periprosthetic hip and knee fractures. Kamara et al. demonstrated a wound complication rate of 22%, of which 16% of infections required oper-

Table 1. Level of evidence and outcome characteristics of the analyzed investigations.

Author	Year	Type	LOE	N	Union Time (Weeks)	Change in Ambulatory Status/%	Malunion/ Nonunion	SSI	Revision	1 Year Post-op Deaths
Mittal et al.	2021	Retrospective	III	34	20	-	0/3	0	4	13
Bonnenvialle et al.	2018	Retrospective	III	47	19.25	-	0/4	2	10	9
Hussain et al.	2018	Retrospective	III	9	20 (18-24)	4 (20%)	0/0	0	0	0
Hoffman et al.	2015	Retrospective	III	27	-	-	0/3	0	3	-
Ebraheim et al.	2014	Retrospective	III	15	16.1 (8-24)	0 (0%)	0/0	0	3	0
Ehlinger et al	2013	Retrospective	III	8	-	-	1/0	0	1	0
Platzer et al.	2011	Retrospective	III	19	26	6 (43.8%)	0/1	0	1	1
Hou et al.	2011	Retrospective	III	7	18.8	0 (0%)	0/0	0	1	2
Soenen et al.	2011	Retrospective	III	10	-	-	0/4	0	4	0
Sah et al.	2010	Retrospective	III	22	13.8 (10-18)	0 (0%)	0/0	0	0	0
Mamczak et al.	2010	Retrospective	III	20	13 (6-22)	7 (35%)	3/0	1	1	0
Chakravarthy et al.	2007	Retrospective	III	12	19.2 (16-28)	3 (25%)	0/0	0	2	1
					Avg Union Time (Weeks): 20.2	% Change: 18.3%	% Malunion / % Nonunion: 1.63%/6.12%	% SSI 1.3%	% Revision 12.6%	1 Year Mortality Rate: 12.8%

LOE: Level of Evidence

ative treatment after previous periprosthetic hip and knee fractures (Kamara, Berliner, and Cooper 2020).

REVISION

A total of 245 patients were analyzed amongst 12 studies with a total of 28 cases of revision, for a revision rate of 12.6% (Table 1). Revisions occurred due to multiple etiologies including nonunion, malunion, surgical site infection, and hardware failure including plate breakage or screw loosening. The majority of revisions were due to malunions or nonunions—analyzed above—followed by revision due to hardware failure (30%) and SSI (13%). Mittal et al. reported on four revision operations: three for nonunion and one for secondary IFF above the plate after union had already occurred (Mittal, Poole, and Crone 2021). Two revisions were seen by Chakravarthy et al., which were both reported as "technical errors" during initial fixation of the IFFs—one less invasive stabilization system (LISS) plate failing at two weeks postoperatively and one implant failure with a new fracture seen at the distal-most screw of the locking compression plating (LCP), which was treated with a retrograde intramedullary nail (Chakravarthy, Bansal, and Cooper 2007). The single revision by Hou et al. was due to a loose hip prosthesis three years after fracture union, which was treated with a proximal femoral replacement.

MORTALITY

Information regarding 1-year mortality was available within 11 studies totaling 203 patients, of which deaths occurred in 26 patients (12.8%). Bonnevialle et al. reported the highest number of deaths with a mortality rate of 18.4% at 6 months postoperatively. They noted that all patients were greater than 80 years old and that seven of those patients were older than 90 years of age. Additionally, patients that had died had a statistically significantly ($p = 0.01$) increased ASA score (3.2 +/- 0.8) compared to patients that did not die (2.5 +/- 0.6) (Bonnevialle et al. 2019). Mittal et al. reported on 13 postoperative deaths. Eight of these patients expired before any postoperative radiographic follow-up, while 5 others died with only 1 radiograph within 2 months of surgery (Mittal, Poole, and Crone 2021). Hou et al. reported on 2 postoperative deaths priors to union (Hou et al. 2011). Platzer et al. reported on a single death occurring on postoperative day 15 due to cardiac arrest (Tosounidis and Giannoudis 2015).

DISCUSSION

The goal of this systematic review and meta-analysis was to evaluate patient outcomes following ORIF of interprosthetic femur fractures. The focus was centered on patient-related outcomes and surgical complications that would possibly require re-operation. The mean time to union across all studies was roughly 20 weeks with nearly 20% of patients experiencing declines in their preoperative ambulatory status. A decline in ambulatory status was defined as a requirement for additional assistive devices for ambulation postoperatively. If patients were able to achieve their pre-fracture ambulatory capacity, then that was not deemed as a decline in status although further information in regards to factors such as distance covered was not discussed in the literature search. Despite the decline in ambulatory status noted in our study, this outcome is an improvement relative to other geriatric fractures. A recent study by Konda et al. noted that at 1 year following operative treatment of geriatric hip fractures, 48% of patients reported a loss of ambulatory status (Konda et al. 2021). In a retrospective review of functional recovery after treatment following periprosthetic distal femur fractures, Ruder et al. demonstrated that, at a mean follow-up of 30 months, 25% of ORIF patients and 14% of revision arthroplasty patients experienced downgrades of functional status to wheelchair dependency. They noted in the study that patients older than 85 years old were more likely to experience loss of functional ambulation status and living independence at one year postoperatively (Ruder et al. 2017). While our study does not extrapolate amongst age, perhaps the fact that interprosthetic fracture patients do not experience limitations secondary to osteoarthritis due to previous joint replacement, permits them to progress with their functional recovery. This provides a critical counseling opportunity for surgeons, specifically with elderly patients, particularly in comparison with other low energy geriatric lower extremity fractures. Regarding rehabilitation, time to union provides an important predictor of possible pain-free ambulation. In their analysis of 22 patients, Sah et al. reported on an average time to union of 13.8 weeks with no patients experiencing declines in ambulatory status postoperatively. Patients were made early protected weight-bearing with an average full weight-bearing at nine weeks postoperatively. They reported success with use of single locked plating without the need for additional strut grafting or dual plating to achieve union (Sah et al. 2010).

Michla et al. emphasized the use of biological augmentation with allograft bone or synthetic agents (BMP) for enhanced biologic ingrowth and construct stability when used in poor bone quality, especially in cases of comminution (Michla et al. 2010). Ebraheim et al. reported an average time to union of 4.02 months. Twenty percent of patients experienced hardware failure requiring reoperation despite reduction and alignment initially being graded as excellent, noting the challenges with healing due to compromised blood supply leading to an increased risk in delayed union, nonunion, and infection (Ebraheim et al. 2014). Mittal et al. reported on 12 patients that were allowed to be immediately weight-bearing as tolerated postoperatively. Eight patients were treated with LCPs, and four patients with a distal femur LISS. They reported two hardware failures attributed to technical error, one in each treatment group, demonstrating that both techniques are viable when used in a locking manner (Chakravarthy, Bansal, and Cooper 2007). Thus, early weight-bearing was safe for patients with these injuries.

Dave et al. was the first to describe a fracture between THA and TKA components (Dave, Koka, and James 1995). This study was later followed by Kenny et al. who coined the term, "interprosthetic femur fracture" after addressing this injury in four patients. All patients in the study ultimately experienced hardware failure requiring reoperation (Kenny, Rice, and Quinlan 1998). Since the publications of Dave et al. and Kenny et al., further investigation has been sparse regarding this rare fracture pattern. Fixation of interprosthetic fractures proves challenging considering that limited bone stock is available for fixation. Due to decreased bone stock, there is concern that interprosthetic fractures may have increased susceptibility to delayed union or nonunion (Platzer et al. 2011). In addition, the transition of stiffness from native bone to implant leads to stress risers further increasing the risk for interprosthetic fracture. Lastly, prior reaming or cementation may further predispose patients to poor fracture healing potential.

Research into this fracture has shown that locked plating techniques do successfully treat patients in the setting of stable prostheses. Locking constructs are advantageous in the setting of these fractures because they provide rigid fixation in the event of osteoporotic bone and assist in achieving near anatomic/anatomic reduction (Soenen et al. 2011; Chakravarthy, Bansal, and Cooper 2007; Scolaro and Schwarzkopf 2017). Prior literature on periprosthetic fracture patterns has demonstrated increased angular stability in osteoporotic bone with locked plating (Chakravarthy, Bansal, and Cooper 2007). Furthermore, these plates can be placed in a manner that causes minimal soft tissue disruption, with preservation of the surrounding periosteum (Sah et al. 2010). In an attempt to span cortical fracture defects by two cortical diameters as originally reported by Larson et al., previous studies recommend spanning the whole femur for stable fixation to avoid nonunion and fixation failure secondary to the elimination of additional stress risers (Moloney et al. 2013; Larson, Chao, and Fitzgerald 1991; Hou et al. 2011; Ehlinger et al. 2013; Scolaro and Schwarzkopf 2017; Tosounidis and Giannoudis 2015).

Cerclage cables may be used as fixation adjuncts that assist in controlling bending forces; however, they perform poorly in resisting axial and torsional loads (Liporace, Yoon, and Collinge 2017). There are concerns that cable placement may add to additional soft tissue dissection that may compromise healing; however, fixation using cerclage cables may be necessary in cases of comminuted fractures at sites of overlap between implants (Platzer et al. 2011; Hou et al. 2011). Cables should be used in conjunction with bicortical and unicortical locking screws when possible (Scolaro and Schwarzkopf 2017).

In a cadaveric biomechanical analysis of peri- and interprosthetic implants of the femur, Lehmann et al. demonstrated that the use of two ipsilateral intrameduallary implants reduced fracture strength by nearly 20% during four-point bending tests when compared to the use of an isolated proximal femoral stem. There was a statistically significant increase in fracture strength during four-point bending tests between two ipsilateral implants when compared with a similar construct with the addition of a lateral locked plate, demonstrating the protective stability provided by the lateral locked plate (Lehmann et al. 2010).

While dual plating has been shown to augment fixation, concerns of additional soft tissue and periosteal disruption do exist (Tosounidis and Giannoudis 2015; Scolaro and Schwarzkopf 2017; Sah et al. 2010; Michla et al. 2010). Despite these concerns, some authors have advocated for the use of dual plating to allow for immediate weight-bearing in periprosthetic/interprosthetic femur fractures (Keenan et al. 2021; Kubik et al. 2021). Keenen et al. demonstrated in their study of 43 patients that medial comminution and non-anatomic reductions were independent predictors for reoperation in patients that were immediately made weight-bearing as tolerated after undergoing isolated lateral locked plating in the treatment of periprosthetic/interprosthetic distal femur fractures (Keenan et al. 2021).

Newer implants, such as the interposition sleeve, have also been undergoing testing in recent years. Weiser et al. demonstrated in their cadaveric biomechanical analysis that the interposition sleeve is an option in the treatment of interprosthetic femur fractures and is especially beneficial in that it allows for early postoperative mobilization. However, the authors noted that interprosthetic fracture strength was greater than failure strength of the interposition sleeve, and that fracture healing with rigid plate fixation is preferred over the sleeve when possible (Weiser et al. 2015).

There has been additional literature demonstrating the efficacy of plate/nail constructs. In their study of nine patients with interprosthetic femur fractures, Hussain et al. used plate/nail constructs to allow patients to be postoperatively fully weight-bearing, noting increased longitudinal and rotational stability provided by the IMN. They noted 100% union at 20 weeks with no nonunions, malunions, or implant failures (Hussain, Dailey, and Avilucea 2018).

There have been multiple proposed classifications regarding interprosthetic fractures, however no consensus has been reached as to which one best validates the fracture pattern. The studies we reviewed provided no helpful classification schemes. While there have been modifications to the Vancouver and Su classifications, additional classifications include those described by Pires et al., Soenen et al., and Platzer et al (Tosounidis and Giannoudis 2015; Soenen et al. 2011; Platzer et al. 2011; Pires et al. 2017). A true classification system should be able to guide treatment and help with prognosis.

A major limitation of this study was that few, if any, studies within this analysis provided raw data or information that assessed the distribution of data, including standard deviations, confidence intervals, etc. Due to this lack of information, we were unable to assess the true distribution of the data. The reason this data was not available is likely that the limited sample size of each individual study was not great enough to perform in-depth statistical analysis. Furthermore, due to the rarity of interprosthetic femur fractures, there are very few eligible studies that examine patient-related outcomes after treatment with significant heterogeneity of reported data. In addition, all studies were retrospective in nature, with no inclusion of prospective, randomized trials. Despite the retrospective data and lack of accurate distribution, this study still provides insight as to what orthopaedic surgeons can expect in the rare, albeit rising, incidence of interprosthetic femur fractures.

This systematic review and meta-analysis provides the most up-to-date foundation for surgeon and patient expectations with regard to union time, postoperative recovery in terms of ambulatory status, and incidence of complications—including surgical site infection, malunion, nonunion, revision, and 1-year mortality. Previous studies have grouped all treatments of interprosthetic fractures, including revision arthroplasty. This study is the first to look at patients solely undergoing ORIF. Future studies, especially those that are prospective in nature, are critical to help further elucidate the aforementioned patient outcomes, as the incidence of this fracture pattern will continue to rise in the coming decades.

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