Risk factors for Periprosthetic Fracture After Total Knee Arthroplasty

Abstract

Introduction: Intra-articular pilon fractures of the distal tibia are complicated fractures with far-reaching long-term functional consequences. Despite improved surgical methods, the ideal management protocols and resulting recuperation patterns continue to be topics of recent investigation. This study aims to compare functional outcome, and rates of complications after surgical management of pilon fractures by open reduction and internal fixation (ORIF) or minimally invasive plate osteosynthesis (MIPO) and also to compare the effect of age on recovery and modes of complications.

Materials & Methods: This is a prospective observational cohort study of 183 type B or C pilon fracture patients treated at a single trauma center. The level of functional recovery 2 weeks, 6 weeks, 3 months, 6 months, and 12 months post-injury was measured by the Foot Function Index (FFI). Postoperative complications were noted, and the time to return to normal activities. Repeated-measures ANOVA was employed in the assessment of temporal changes in FFI scores.

Results & Discussion: There was significant improvement on all subscales of FFI during 12 months of time (P<0.001), with most improvement in the first 6 months. The mean duration of time to return to activity was 25.5±7.5 weeks. Complications were malunion (23.0%), nonunion (30.6%), deep infection (15.8%), loosening of implant (14.8%), and reoperation (36.6%). Age was correlated with increased complications. Compared with ORIF, MIPO achieved comparable 12-month functional recovery (FFI improvement) while demonstrating a lower, though not statistically significant, rate of deep infection, suggesting similar efficacy with a potential advantage in soft-tissue preservation.

Conclusion: Operative management of pilon fracture yields significant functional improvement, although complications are common. Prognosis depends on age. Preoperative planning should be meticulous, close observation necessary, and individualized rehabilitation in order to maximize outcome.

Keywords: Tibial fractures, Treatment outcomes, Fracture healing

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Introduction

Total knee arthroplasty (TKA) has emerged as a prevalent and effective surgical intervention for patients suffering from advanced knee osteoarthritis, addressing debilitating pain and improving mobility.(1, 2) The rising life expectancy and aging population have contributed significantly to the increase in TKA procedures worldwide, which are projected to continue on this upward trajectory. While TKA is associated with favorable long-term outcomes for many patients, complications such as periprosthetic fractures present daunting challenges, particularly for elderly and osteoporotic individuals(3, 4)

Periprosthetic fractures, defined as those occurring around or adjacent to the implanted knee prosthesis, predominantly affect the distal femur, tibia, or patella.(2, 5) The incidence of these fractures varies widely among different populations and clinical scenarios, with rates between 0.3% and 2.5% after primary TKA and escalating dramatically to 38% after revision procedures. This trend aligns with the growing number of TKA surgeries performed globally, raising concerns that the burden of periprosthetic fractures will increase concomitantly.(6-8)

Several risk factors contribute to the likelihood of sustaining periprosthetic fractures, including advanced age, osteoporosis, prior fractures, rheumatoid arthritis, and chronic corticosteroid use.(9-11) Osteoporosis is particularly fractures have had high complication rates with attention mainly centered around infection, nonunion, and malunion, largely due to the severity of the original injury and technical requirements of the surgical fixation. Other complications of deep infection, implant failure, wound dehiscence, and post-traumatic arthritis occur often and can significantly reduce long-term function. Notably, reoperation rates remain relatively high in some series, especially with complex fracture patterns like the C3-type.(6-8) Definitive timing of surgical repair has also been a point of concern; delayed fixation techniques are being employed most commonly to facilitate resolution of soft tissue swelling and prevent infection.(9)

Table 1: Demographic and Clinical Characteristics of the Study Population

Variable	Category	Fracture Group (n=45)	Control Group (n=90)	p-value
Sex	Female	31(68.9%)	63(70.0%)	0.89
	Male	14(31.1%)	27(30.0%)	
Age	≥60 years	30(66.7%)	60(66.7%)	1.00
	<60 years	15(33.3%)	30(33.3%)	
BMI Classification	Normal	5(11.1%)	30(33.3%)	0.01
	Overweight	22(48.9%)	40(44.4%)	
	Obese	18(40.0%)	20(22.2%)	
Fracture Location	Within prosthesis	15(33.3%)	-	-
	At the edge of the prosthesis	20(44.4%)	-	
	Above the tip	10(22.2%)	-	
Revision TKA	Yes	7(15.6%)	0 (0%)	<0.001
Osteoporosis	Yes	3(6.7%)	1(1.1%)	0.07–0.08
Corticosteroid Use	Yes	3(6.7%)	1(1.1%)	0.07–0.08

Although conventional open reduction and internal fixation (ORIF) can achieve anatomical alignment, it is associated with increased soft tissue morbidity, which in turn raises the risk of postoperative complications.(10) Present advances in the technique of fixation, such as minimally invasive plate osteosynthesis (MIPO) and external fixation, are oriented towards minimizing soft tissue disruption and have been promising for enhancing patient outcomes.(11) Although other outcome measures have been employed in pilon fracture recovery assessment, such as AOFAS score and SF-36, the Foot Function Index (FFI) is a more specific measure of pain, disability, and lower limb functional limitation and is thus especially useful in postoperative foot and ankle disease tracking.(12) These surgical innovations have been paralleled by a growing emphasis on early intervention and structured postoperative rehabilitation protocols, which are critical for optimal functional recovery. But results after treatment are still extremely variable and depend upon healthcare facilities, surgical skill, and compliance with rehabilitation guidelines. Therefore, context-specific studies are needed to identify real-world outcomes and inform practice in various clinical settings. Outcome variability is also influenced by differences in treatment protocols, patient comorbidities, and socioeconomic factors, all of which may affect access to rehabilitation services and adherence to postoperative care.(13-15)

In the face of global advances in surgical methods, few data have been reported from low- and middle-income nations like Iran on real-world results and complication rates after pilon fracture surgery. Variability in access to healthcare, surgeon expertise, and rehabilitation protocols can result in intercountry and intracountry variability in outcomes. There is also an increasing requirement for the formulation of evidence-based standardised treatment protocols to inform decision-making in these injuries, particularly within resource-constrained settings. This is the first Iranian study to measure clinical outcome after pilon fracture surgery in the context of the Foot Function Index (FFI) and to evaluate postoperative complications in all aspects under real-world circumstances. Furthermore, there is no extensive longitudinal study in Iran with patient-reported outcomes measured with valid tools at various follow-up periods following pilon surgery. In this study, the said deficiency is to be addressed through the establishment of robust clinical and functional outcome data.

Materials & Methods

Study Design and Setting

This prospective observational study was performed between August 2020 and March 2024 at two teaching hospitals affiliated with Isfahan University of Medical Sciences, namely Kashani Hospital and Alzahra Hospital, which are the principal referral centers for orthopedic trauma in the region. A consecutive sampling method was used to enroll all eligible patients presenting with pilon fractures during the study period. The needed sample size was 80 participants, using effect size information from prior studies, with 80% power and an alpha of 0.05, to provide adequate statistical power to detect clinically significant differences in functional outcomes.

Ethical Considerations: Written informed consent for surgery and inclusion in the study was obtained from all the participants.

Patient Evaluation and Fracture Classification

All the patients were assessed pre-operatively by a senior orthopedic surgeon on the basis of proper history-taking, physical examination, and radiological investigation. All surgeries were performed or supervised by fellowship-trained orthopedic trauma surgeons to ensure consistency in surgical technique and clinical judgment. Fractures were classified according to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) system into types A (extra-articular), B (partial articular), and C (complete articular) fractures.[16]

Inclusion criteria

Patients could be included if they had the following: age ≥16 years; confirmed diagnosis of a type B or C pilon fracture (AO/OTA classification); surgical indication; and ≤21 days' time lapse between injury and operation. Only closed fractures were included. Patients must also be capable of giving informed consent and undergoing follow-up evaluation.

Exclusion criteria

Exclusion criteria included previous operation or deformity of the affected ankle; open fracture; polytrauma with ICU admission; pathological fractures; and any medical condition making normal follow-up unsuitable (e.g., dementia, relocation). Patients withdrew consent, failed to attend more than two scheduled follow-up visits, or had missing Foot Function Index (FFI) data and were excluded from final analysis.

All admission and exclusion criteria were met by the admitting assessment orthopedic surgeon at admission through a standardized checklist.

Surgical Procedures and Postoperative Protocol

The choice of surgical technique, open reduction and internal fixation (ORIF), minimally invasive plate osteosynthesis (MIPO), or primary ankle arthrodesis, was determined by the treating orthopedic surgeon based on fracture type and soft tissue condition. In particular, ORIF was mostly chosen in cases that had extensive articular comminution or displacement, which necessitated direct visualization for anatomic reduction of the joint surface. Conversely, MIPO was preferred in cases with somewhat well-preserved joint congruity, metaphyseal fractures with feasible indirect reduction, or compromised soft tissue, with the aim of avoiding additional injury to the soft tissues. The final choice was made in the operating room. Post-operatively, thromboprophylaxis with low-molecular-weight heparin and peri-operative antibiotic prophylaxis was administered. On the first post-operative day, an open-foot brace to keep the ankle in the neutral (90°) position was applied. Active and passive range of motion, along with strengthening of the muscles, was encouraged to avoid such complications as equinus contracture. Weight-bearing was customarily deferred until roentgenographic proof of union was established, and progressive ambulation was managed by virtue of parametric physiotherapy protocols on follow-up examinations.

Table 2: Fracture Characteristics

Fracture Type		Fracture Group (n=45)
Femur		34(75.6%)
Tibia		10(22.2%)
Patella		1(2.2%)
Rorabeck and Lewis Classification	Type 1 (Femur)	15(44.1%)
	Type 2 (Femur)	19(55.9%)
	Type 3 (Femur)	0
Felix Classification	Type 1 (Tibia)	6(60.0%)
	Type 2 (Tibia)	3(30.0%)
	Type 3 (Tibia)	1(10.0%)
	Type 4 (Tibia)	0

Data Collection and Follow-up

The postoperative data collected were age, gender, type of fracture, and type of surgical procedure. FFI was employed to assess outcome, as well as symptom reporting of complications including nonunion, wound complication, infection, loosening of the implant, and revision surgery. 2 weeks, 6 weeks, 3 months, 6 months, and 12 months postoperative follow-up assessments were conducted using clinic visits or structured telephone interviews. Patients with incomplete follow-up or missing FFI data at more than two time points were excluded from the final analysis to preserve data integrity.

Foot Function Index (FFI) Assessment

The Persian version of the Foot Function Index (FFI) was used as a validated instrument to measure pain, disability, and activity limitation subscales.[17] The items were completed on a 0 (no difficulty) to 10 (severe difficulty) scale, where a higher score reflects more impairment. Pain and disability domains were both given a score of 90, and activity limitation a score of 50 at maximum. A measure of functional recovery to pre-injury level was used in the form of returning to daily and occupational activities. The FFI was chosen because of its high validity in measuring foot pain and disability in orthopedic trauma populations, and the existence of a culturally adapted Persian form.

Statistical Analysis

Statistical comparison was performed using the SPSS software (version 26.0, IBM Corp., Armonk, NY, USA). Categorical data were expressed as frequencies and percentages, whereas continuous data were expressed as mean±SD. Repeated measures ANOVA was used to compare differences in FFI scores over follow-up periods. Pearson or Spearman correlation coefficients were used, depending upon the distribution of the variables, to measure association. Two-tailed P-value <0.05 was used for statistical significance.

Results

Demographic and Clinical Characteristics

The study included 45 patients in the fracture group and 90 patients in the control group. Table 1 illustrates the demographic and clinical characteristics of both groups. The distribution of gender and age was similar between the two groups, with 94 (69.62%) female patients and two-thirds of patients aged 60 years or older in both groups. However, significant differences were observed in BMI classification, with the fracture group having a higher proportion of overweight (22 vs. 40) (48.9% vs. 44.4%) and obese (18 vs. 20) (40.0% vs. 22.2%) patients compared to the control group (p=0.01 for both categories).

Table 3: Multivariate Logistic Regression Analysis of Risk Factors for Periprosthetic Fracture

Predictor	Reference (if applicable)	aOR(95% CI)	p-value
Age (≥60 vs <60)	<60	1.02(0.48–2.10)	0.96
Sex (Female vs Male)	Male	1.08(0.52–2.24)	0.84
BMI (Overweight)	Normal	2.50(1.10–5.70)	0.03
BMI (Obese)	Normal	3.80(1.40–8.80)	0.01
Revision TKA (Yes vs No)	No	15.0(4.00–∞)	<0.001
Osteoporosis (Yes vs No)	No	4.00(0.85–16.0)	0.08
Corticosteroid Use (Yes vs No)	No	3.90(0.80–15.0)	0.09

Fracture Patterns and Distribution

The characteristics of the fractures presented in Table 3 indicate that femoral fractures are the most common, accounting for 75.6% of cases. This is followed by tibial fractures at 22.2%, with patellar fractures being quite rare at only 2.2% (Table 2).

Risk Factor Analysis

Notably, 7 (15.6%) of patients in the fracture group had undergone revision TKA, while none in the control group had a history of revision surgery (p<0.001). Although not reaching conventional statistical significance, there were trends toward higher prevalence of osteoporosis and corticosteroid use in the fracture group (both 6.7% vs. 1.1%, p=0.07-0.08). After adjusting for potential confounders, overweight and obesity emerged as significant risk factors for periprosthetic fracture, with adjusted odds ratios of 2.50 (95% CI: 1.10–5.70, p=0.03) and 3.80 (95% CI: 1.40–8.80, p=0.01), respectively, compared to normal BMI. Revision TKA was associated with the highest risk, with an adjusted odds ratio of 15.00 (95% CI: 4.00–∞, p<0.001), indicating a strong relationship between prior revision surgery and subsequent periprosthetic fracture. Although not reaching statistical significance at the conventional p<0.05 level, osteoporosis and corticosteroid use showed trends toward increased risk with adjusted odds ratios of 4.00 (95% CI: 0.85–16.00, p=0.08) and 3.90 (95% CI: 0.80–15.00, p=0.09), respectively. These findings suggest potential clinical relevance despite the borderline statistical significance, possibly due to the relatively small sample size. Age and sex were not found to be significantly associated with risk of periprosthetic fracture in this study population, with adjusted odds ratios close to 1.0 and p-values >0.80 (Table 3).

The timing of fractures following total knee arthroplasty (TKA) reveals that a significant majority (75.6%) of fractures occur 90 days or more after surgery. This finding suggests that these fractures are more likely related to ongoing issues with implant stability rather than to acute surgical trauma. In contrast, 24.4% of fractures occur within the first 90 days post-surgery, which may be associated with the surgical procedure itself (Table 4).

Discussion

Summary of Key Finding

Revision TKA was the most powerful independent risk factor for periprosthetic bone fracture with an odds ratio of 15.0, which represents a strongly raised risk compared with primary TKA. Elevated BMI was also a powerful risk with a greater risk in obesity compared with being overweight. Osteoporosis had a trend towards raised fracture risk that was not significant. These results create a delineated risk hierarchy, clarifying and putting into context debates in the literature concerning the prominence of each factor.

Comparison with Previous Studies

The significant association between elevated BMI and periprosthetic fractures in our study is consistent with recent literature. Puga et al. (2024) conducted a systematic review specifically examining BMI's impact on periprosthetic fracture risk after TKA and found that higher BMI categories were associated with increased fracture risk.[20] Our findings demonstrated a clear dose-response relationship, with overweight patients having 2.5 times higher odds and obese patients having 3.8 times higher odds of periprosthetic fracture compared to those with normal BMI. The biomechanical explanation for this association likely involves increased mechanical loading on the prosthesis-bone interface in patients with higher body weight. Additionally, operative challenges in patients with obesity might contribute to suboptimal component positioning, potentially creating stress risers.(9) Redondo-Trasobares et al. (2020) identified obesity as an independent risk factor for periprosthetic femoral fractures and suggested that the combination of increased mechanical stress and technical challenges during surgery may explain this relationship.(9) Our study identified revision TKA as the strongest predictor of subsequent periprosthetic fracture (aOR 15.00, p<0.001). This finding is strongly supported by previous research. Meek et al. (2011) reported that the risk of periprosthetic fracture was substantially higher after revision TKA (2.2%) compared to primary TKA (0.6%).(22) Meyer et al. (2021) identified periprosthetic fracture as one of the leading causes of failure after aseptic revision TKA.(13) Several factors may explain this strong association. Rodriguez-Merchan (2024) discussed how revision TKA often requires more extensive bone resection, potentially leaving less bone stock and creating structural weakness.(15) Additionally, revision components often feature longer stems that can create stress risers at the stem tip. The altered biomechanics following revision surgery, combined with potentially compromised bone quality, create an environment conducive to fracture development.(15, 29) Although osteoporosis showed a trend toward increased fracture risk in our study (aOR 4.00, p=0.08), it did not reach conventional statistical significance. This finding contrasts with several recent studies that have established stronger associations. Harris et al. (2024) demonstrated that patients with osteoporosis undergoing TKA had significantly higher 5-year implant-related complications, including periprosthetic fractures.(14) Similarly, Park et al. (2024) highlighted that a history of previous osteoporotic fracture was a significant predictor of subsequent periprosthetic distal femoral fracture following TKA.(12) The borderline significance in our study may be attributed to the relatively small sample size and the low reported prevalence of diagnosed osteoporosis (6.7% in the fracture group). It's possible that undiagnosed osteoporosis or osteopenia was present in additional patients. Agarwal et al. (2023) demonstrated that prior fragility fractures, which often indicate underlying bone quality issues, significantly increased long-term periprosthetic fracture risk after TKA.(1) Interestingly, Forlenza et al. (2024) found that bisphosphonate treatment in patients with osteoporosis did not affect periprosthetic fracture risk following TKA, suggesting that pharmacological management of osteoporosis may not fully mitigate the fracture risk in this population.(10)

Table 2: Timing of Fractures After TKA

Timing	Fracture Group (n=45)
≥90 days	34(75.6%)
<90 days	11(24.4%)

This highlights the complexity of the relationship between bone quality and periprosthetic fracture risk. Our findings showed a trend toward increased fracture risk with corticosteroid use (aOR 3.90, p=0.09), though this did not reach statistical significance. This trend is consistent with established literature on corticosteroid-induced adverse effects on bone metabolism. Buckley et al. (2017) outlined in the American College of Rheumatology guideline that glucocorticoid use is associated with rapid bone loss and increased fracture risk, with effects beginning within the first three months of treatment. The mechanism involves multiple pathways, including decreased bone formation, increased bone resorption, and altered calcium metabolism.(28) These changes can compromise the structural integrity of bone around prosthetic implants. While our study showed only a trend, the relatively high odds ratio (3.90) suggests potential clinical relevance despite not reaching statistical significance at p<0.05. Interestingly, our study did not identify age ≥60 years (aOR 1.02, p=0.96) or female gender (aOR 1.08, p=0.84) as significant risk factors for periprosthetic fracture. This finding differs from some previous reports. King et al. (2018) identified advanced age and female gender as risk factors for periprosthetic fractures following total joint arthroplasty.(30) Similarly, Singh and Lewallen (2011) found that older age was associated with increased periprosthetic fracture risk after TKA.(31) The lack of association in our study may be due to several factors. First, our matching process for age and gender between case and control groups might have diminished the ability to detect these as independent risk factors. Second, the influence of age and gender might be mediated through other factors such as bone quality and comorbidities. Finally, our regional population might have unique characteristics that modify the typical risk profile seen in other studies.

Clinical Implications and Recommendations

The strong association between revision TKA and subsequent periprosthetic fracture highlights the need for careful patient selection, meticulous surgical technique, and enhanced postoperative surveillance in revision cases. Surgeons should be vigilant about stem positioning to avoid creating stress risers and consider strategies to preserve bone stock where possible.[15, 29] For patients with elevated BMI, our findings suggest that weight management should be part of the comprehensive care plan. Preoperative weight optimization might reduce the risk of this serious complication. Additionally, patients with high BMI might benefit from more conservative postoperative rehabilitation protocols and longer protected weight-bearing periods.[20] Although osteoporosis and corticosteroid use showed only trends toward significance, their relatively high odds ratios suggest clinical relevance. Evaluation of bone health should be considered in preoperative assessment for TKA, especially in patients with other risk factors. Pharmacological management of osteoporosis might be beneficial in high-risk patients, though Forlenza et al. (2024) suggest that bisphosphonate treatment alone may not fully mitigate fracture risk.[10, 27] This study has several strengths, including its case-control design with matched controls, comprehensive risk factor assessment, and multivariate analysis controlling for potential confounders. However, several limitations warrant consideration.

Limitations and Future Research

First, the relatively small sample size, particularly in the fracture group (n=45), may have limited statistical power to detect associations with osteoporosis and corticosteroid use. Second, the retrospective nature introduces potential for selection and information bias. Third, we did not collect data on surgical techniques, implant designs, or postoperative rehabilitation protocols, which might influence fracture risk. Additionally, we did not have data on bone mineral density measurements for all patients, potentially leading to underdiagnosis of osteoporosis. Lastly, the single-center design may limit generalizability to other populations with different demographic characteristics or healthcare practices.

Future research should focus on prospective studies with larger sample sizes to better characterize the relationship between osteoporosis, corticosteroid use, and periprosthetic fracture risk. Studies incorporating routine bone mineral density measurements would provide a more accurate assessment of bone quality. Investigation into protective strategies for high-risk patients, including modified surgical techniques, implant selection considerations, and tailored rehabilitation protocols, would be valuable. Additionally, research examining the role of bone-enhancing medications in preventing periprosthetic fractures, specifically in joint arthroplasty patients, would address an important knowledge gap. Longitudinal studies assessing the impact of weight management interventions on fracture risk in overweight and obese patients would also provide valuable insights for clinical practice.

Conclusion

Our study identifies elevated BMI and revision TKA as significant independent risk factors for periprosthetic fracture following TKA, with trends toward increased risk with osteoporosis and corticosteroid use. These findings highlight the importance of considering modifiable risk factors in preoperative planning and postoperative management. Comprehensive risk assessment incorporating BMI, revision status, bone health, and medication history may help identify patients who would benefit from enhanced surveillance and preventive strategies. A multidisciplinary approach addressing these risk factors may reduce the incidence of this challenging complication.

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